DISCOVERY

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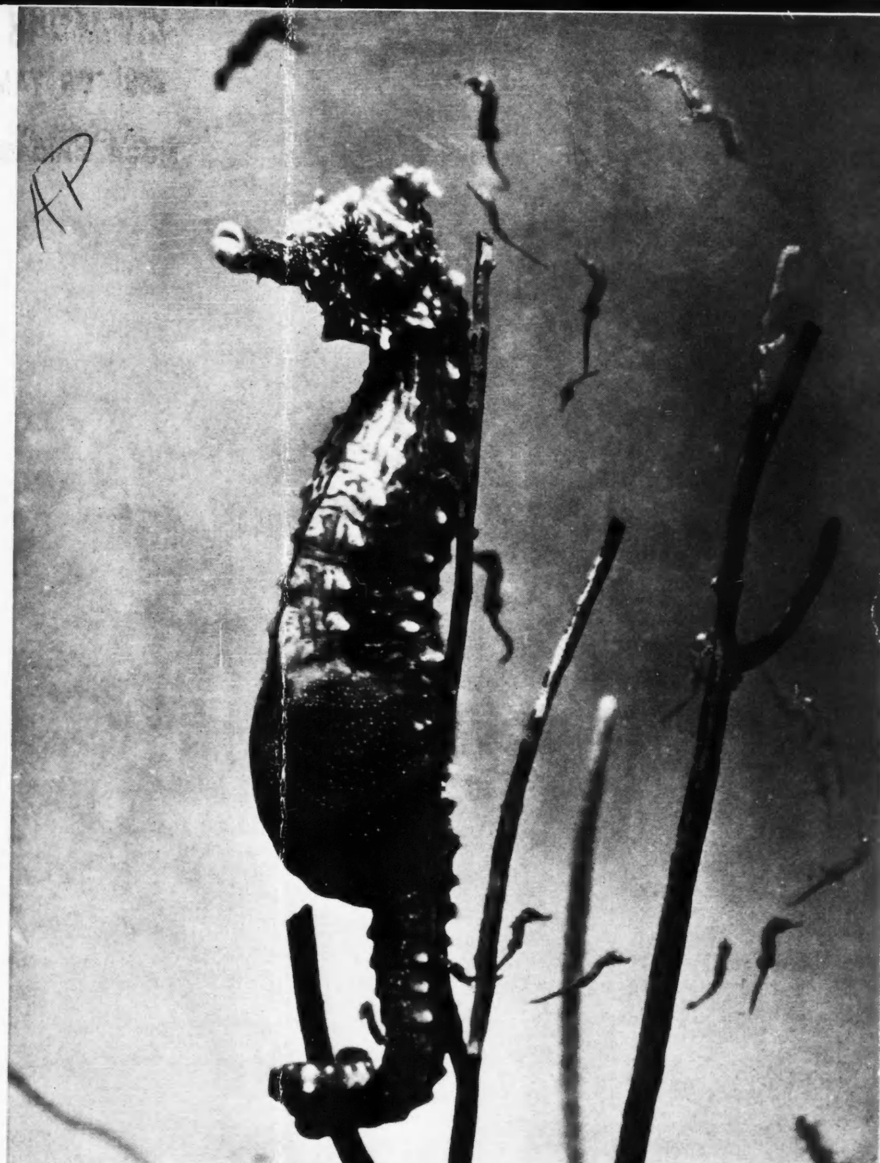

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THE MAGAZINE OF SCIENTIFIC PROGRESS

May, 1952 Vol. XIII. No. 5

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The Progress of Science

U.S. Emigration

It is not always wise to believe everything that one reads in the Sunday papers. For the stories such papers print have to be made sensational if they are to compete with the claims of sleep or gardening. Since snow one recent weekend made the garden a *hortus inclusus*, a story about the attractive salaries offered to British scientists who are prepared to emigrate to the U.S.A. doubtless had some impact. There was nothing particularly novel about this article in fact, for since the beginning of the year *The Times* has been carrying ads of the DuPont Company for various types of specialists wanting employment in their American establishments. The Sunday paper came down to cases, and alleged that a leading British expert on antibiotics had been offered £14,000 a year to emigrate while a university nuclear physicist, on a salary of £1500 a year here, was being tempted with a bait of £6000 in America.

Before anybody starts to pack his bags, there are a few other considerations to be taken into account. In a foreign land, it still remains necessary to serve, not seven years for Ruth, but *seven plus seven*. The salaries offered have to be scaled to the cost of living, which is roughly three times what it is here.* It is not necessary to set out everything involved in detail: some prices are on one side, some on the other side of the 'three times' mark. One item to be considered is the cost of housing; a typical house—what would be called a wooden bungalow here—will cost 30,000 dollars in the New York area. At 2·80 dollars to the pound, the conversion figure used by this particular Sunday paper, that makes a small establishment nearer eleven thousand pounds than ten. The accommodation on the one floor would be a living room, a 'den' (or small study), a kitchen, three bedrooms and a bathroom. The bungalow would include all the gadgets like refrigerators and a gas-fired central heating system, both of which are essential with the climatic extremes of New York. The gas-heating is one of the triumphs of U.S. life, clean methane being piped 2000 miles from Texas into the heart of the city and, with the advantage of cleanliness and being on tap, competing on price for equivalent heat with solid fuel at over £10 a ton. The wooden house can certainly be made comfortable. If, however, you hanker for bricks and mortar the purchase price will go up to 40,000 dollars.

It is clear that a sort of dimensional analysis is required before comparisons can be drawn between conditions there and here.

The other point for consideration is the position of this country. The scientists who are wanted in America are wanted as much, if not more, in this country. They are the technologists whose peculiar value is their ability to transmute laboratory research into practical operation—the nuclear physicists, electronic engineers, statisticians, chemical engineers and microbiologists. They have nearly all been educated at the expense of the tax- and rate-payers of the country, and they represent an investment which should be repaid. If the movement to migrate reaches any size, it will be legitimate for the scope of the Control of Engagements Order to be extended. It would be regretted, but no more than the restrictions which have to be imposed on imports while the sterling area is in difficulties. Absolutely free interchange of scientists and scientific information has ceased to be possible and desirable, just like Free Trade.

The only exchanges left, apart from academic ones under the Fulbright scheme, are those sponsored by the Government, particularly for management and production studies. The conclusions which will be drawn from American practice may not be very welcome to technologists here, and might be another reason to pause before answering the advertisements. A good deal of the power of American technical achievements derives from breaking down scientific jobs into fragments. The common run of technologist has to be efficient in a limited field and account for all his time, even to the extent of booking it to job numbers. There are very few of the people right at the top who know how to break a job down and bring it all together. Their positions are not readily available to the stranger, although

* For comparative purposes, one can take the starting salary of a New York policeman which is about £1000; any London policeman on the beat might well be glad to have that much!

a time-card might be—but, as Runyon says, there is no percentage in that!

Franklin's Kite and Conductor

THE bicentenary of Benjamin Franklin's famous kite experiment for 'collecting' atmospheric electricity, coinciding with the first practical demonstration of Franklin's lightning conductor by two French philosophers, is well worthy of commemoration. For here was yet another instance of Franklin's ideas applied to useful ends, another example of scientific reasoning, or assessing possible results as far as the knowledge of his day permitted him, which when put to the test proved the soundness of his reasoning. Franklin was versatile, to say the least. To his score were added such diverse subjects as artificial fertilisers, bifocal eyeglasses, the use of oil for calming rough seas, and the differentiation of positive and negative electricity which won for him the Copley medal of the Royal Society in 1753. But the kite and the lightning conductor, following his 'Philadelphia experiments' on static electricity, using the newly discovered Leyden jar, capture our imagination.

Before 1752 Franklin had written much regarding his convictions that lightning was nothing more than a large-scale demonstration by nature of electrical discharges of the same type as those from Leyden jars. Very soon he passed on to the observation that "points sending off or drawing on the electrical fire" might be applied to make secure from lightning "houses, ships, and even towers and churches". On top of "weathercocks, vanes, or spindles of churches or masts of ships" there should be placed, he argued, a rod of iron 8–10 feet in length, sharpened gradually to a point like a needle. The iron might be gilded to prevent rusting; and it might be divided into a number of points "which would be better", since "the electrical fire would, I think, be drawn out of a cloud". Next he thought of adding "a wire down the outside of the building into the ground, or down round one of the shrouds of a ship and down her side till it reaches the water". Since Franklin stipulated iron protected from rust; since he suggested a number of points in place of one, we can forgive him one extra point which would have been dangerous, to say the least. He believed that a man could be stationed in a kind of sentry-box on top of a building in readiness to test for electric shocks! (This was before the episode of 1753 when the Swedish physicist Richmann was killed at St. Petersburg as a flash struck his conductor.) Although British architects stipulated copper tape for lightning conductors in modern days, since iron in our wet and smoky atmospheres would soon become unsightly and rust away, American and European authorities often preferred iron. For though copper is a better conductor of electricity, iron with a superior impedance allows the flash to 'leak' away by damping oscillations.

The year 1752 provided an illustration of France of that period ever providing the means to further the development of science. Franklin's observations on electricity made at Philadelphia were not to fall on stony ground after Buffon of the Jardin du Roi (later the Jardin des Plantes) got D'Alibard to publish a translation of the treatise. At once practical experiments were put in hand by D'Alibard and De Lor. On May 10, 1752, a loud thunder-clap came just when D'Alibard was off duty, away from the 40-ft. iron rod pointed with brass which had been erected. But the faithful dragoon Coiffier was on guard with a Leyden jar intended for charging—if Franklin's ideas were correct. Coiffier, like Faraday's faithful sergeant, ever ready for duty noted the powerful crackling sparks and drew off some 'electric fire' without suffering the fate of Richmann. And when De Lor was able to repeat the experiment on May 18, Franklin's fame was in the ascendancy, to say the least. In his autobiography he tells how his book was given a "more sudden and general celebrity" with D'Alibard and De Lor's experiments. The French king and the court were impressed; our Royal Society waived the 25 guineas fee for membership; and American universities awarded degrees to Franklin in days when his writings were being translated into German and Italian.

"When I was a boy, I amused myself by flying a kite", wrote Franklin in telling us something of himself. Years later he repeated the pastime—with a difference. The curious point regarding the 1752 kite-flying incident was that only 15 years afterwards did the details appear in print, and this from the hand of Joseph Priestley to whom Franklin had communicated the information. Franklin took a silk handkerchief and two cross-sticks, constructed a rough form of kite, and took his son with him to fly it since he dreaded the ridicule of any spectators who might be present. He soon observed some loose hempen threads on the string standing erect as they became electrified; and he received a spark on his knuckle. "When the rain had wet the string" he collected "electric fire very copiously", while a Leyden jar could be charged. This kite experiment came in June 1752, a month after the French demonstration that Franklin's views on lightning were correct; but Franklin had not heard of this.

Although De Romas also became credited with an independent kite experiment; although Lemonnier noted atmospheric electricity even in fine weather, and Oliver Lodge became pioneer in multiple-point lightning conductors, all histories of this subject must begin with Franklin, diplomat *and* scientist.

The Incomparable da Vinci

THE life and achievements of Leonardo da Vinci (1452–1519) have for long exercised the minds of thoughtful men, and the present exhibition of his drawings arranged by the Royal Academy at Burlington House has served to reawaken an interest in him among younger people for whom he has been little more than a name.

Two questions of great interest suggest themselves after seeing these pictures at the exhibition. Does versatility interfere with achievement and did it do so with da Vinci? Furthermore, is it possible for a man to be pre-eminent both as a creative artist and a probing scientist?

There is no doubt at all about da Vinci's versatility. When he was not painting or studying painting he was studying anatomy and physiology or inventing devices for court entertainments or devising new irrigation schemes or suggesting a drastic reform in the sanitary system of a city in order to avoid further plague—and these are only a few of his activities. When he wrote a letter commending himself to the service of Ludovico Sforza, the Duke of Milan,

SCIENTIFIC JARGON

THE literati of the scientific world have not infrequently written to *The Times* deploring the use of commercial jargon and Civil Service jargon, which are just as baffling to the uninitiated as the office switchboard or the battery of telephones the big-business man keeps on his desk. But such persons we find are liable to be shocked if they happen to overhear a healthy slab of barrack-room slang or the language of the porters of Covent Garden, Smithfield or Billingsgate. For scientific jargon is just as baffling in its own way as any other kind of jargon. This is well brought out in the issue of *The Spectator* of April 4, 1952, in which Wilfrid Blunt considers the 'jargonisation' of botanical nomenclature.

He comments as follows: "Now it may well seem an admirable idea to immortalise the great botanists of the past by naming a genus or a species in their honour; unfortunately, however, their names are not always very well designed for reposing in the memory or for slipping lightly off the tongue. That *Michauxia Tchihatcheffi* is not more frequently grown may in part be due to a certain difficulty in referring to it in public. Names like *Townshendia Wilcoxeana* are perhaps easier, but they are far from beautiful; and I do not know that much was gained (except, no doubt, from a scientific point of view) by changing *Higginsia Ghiesbreghtii* to *Hoffmannia Ghiesbreghtii* *Cheirostemon* is admittedly better than *Macpalxochitlquahuitl*; but what about *Zantedeschia Lutwychei, Dizygotheca Kerchoveana, Gutierrezia gymnospermoides, Warscewiczella Wailesiana* and *Echinofossulocactus Wippermannii*? How do you like the *Schombolaeliocattleya* hybrids?"

Mr. Blunt continues: "Then there is that cosmopolitan genus the Odontoglossum, with such forbidding specific names as *Imschootianum, Hrubyanum, Uro-Skinneri, Boddaertianum, Godseffianum,* and *Vuylstekeanum*. (I feel as though I could pronounce the last of these, but I may be wrong.) Reginald Farrer, in *The English Rock Garden*, has a good sentence about *Paeonia Mlokosewitschi*: 'This pleasant little assortment of syllables should be practised daily, but only before dinner (unless teetotal principles of the strictest are adopted), by all who wish to talk familiarly of a sovereign among paeonies —a rare plant, and rendered almost impregnable by its name.' But it must not be forgotten that we can give as good as we take; I should very much like to conceal myself behind the Iron Curtain when the Russian botanists are talking about their colquhounias. Again, though it is clearly appropriate to name flowers after botanists when they are associated with their discovery or introduction—e.g. *Gentiana Farreri*—the practice is misleading when no such connexion exists. The good old herbalist Fuchs had been dead for more than a century when Plumier discovered an American plant which he named fuchsia in his honour; and the memory of the Rev. Adam Buddle, a seventeenth-century country rector with a taste for mosses, is ill kept green by the flaunting, exotic buddleia. (This, incidentally, is a good example of an unpromising name which has become quite euphonious.)"

There is also a great deal of difficulty with regard to the 'proper' pronunciation of these various terms. For example, *Fuchsia* is named after Fuchs, and so the current pronunciation seems to be 'improper' etymologically. In the same way the pronunciation *veronica* cannot be defended if we abandon the probable derivation "from βερονίκη, in favour of the improbable one from the Arabic *virro nikoo* (beautiful remembrance). Other examples of common mispronunciations are: crocus ('o' should be short), lilium (first 'i' long), anemone ('o' long and stressed) clematis ('e' long and stressed), azalea (second 'a' short), and rhododendron (first 'o' short). These pronunciations only apply to scientific usage; anémone (sometimes even spelt anemony) and crocus are now as English as the English pronunciation of the word 'Paris'."

How *camellia* ever came to be pronounced *cameelia* is also a mystery; for the plant is supposed to take its name from Father Kamel, a seventeenth-century Moravian Jesuit.

Mr. Blunt concludes his article by stating that he considers that the botanists' most irritating trick is to change the name of a plant just as soon as one has managed to commit it to memory. He concludes: "I am glad to see that a member of the Garden Club of America has launched a powerful attack on this procedure, and that the Royal Horticultural Society has had the courage to reprint it in its journal. The author quotes the best-known and most flagrant example. When I was young there was a popular shrub called *Pyrus japonica*, known familiarly as 'japonica'. As a child I can remember my mother saying: 'Come and look at the japonica.' But I knew better: I had discovered it was really a pyrus. No sooner had I mastered the name than the botanists changed it to *Cydonia lagenaria*. Again I caught up, only to find it rechristened *Cydonia japonica*. And now, as you doubtless know, it has become *Chaenomeles lagenaria*! No film-star, no Paris street, could be more inconsistent in nomenclature. My criticisms, I admit, are mainly destructive. The botanists have got us all into this fix, and it is for them to get us out of it. Of course, specific names can be, and not infrequently are, sensible and informative—e.g. *microphyllus* (small-leaved), *cristatus* (crested)—and this method of naming might become the universal practice."

In fact, there is about nomenclature an atmosphere of 'much ado about nothing'. After all the fuss and bother which is bound to arise when one tries to find out exactly what was the first name given to a particular plant, one is simply driven to the conclusion that names do not matter very much so long as our friends understand what we are talking about! It is all rather reminiscent of the Australian aborigine who did not know the name of a particular marsupial, said in his native language that he did not know what it was called, and so ended up by coining the word 'kangaroo', which is an inaccurate phonetic rendering of the aboriginal expression for "I-don't-know"!

he listed his qualifications as a military engineer under nine heads, as a civil engineer under one, and then added a final paragraph: "Item. I can carry out sculpture in marble, bronze, or clay, and also I can do in painting whatever may be done, as well as any other, be he who he may." (This letter, in reproduction, is exhibited at Burlington House.)

This is not all. He was a personable young man of wit and address, the centre of discussion wherever he appeared.

One is tempted to say that all his versatility did interfere with his actual achievement, despite his very great powers of concentration. (A lesser man with the same versatility would have become diffuse, frittering away time on a series of inconclusive designs.) Consider the case of the famous bronze horse. One of the designs to be carried out when he joined the Sforza household in about 1483 was an equestrian statue in memory of Francesco Sforza. The artist did many sketches of horses, but after seven years, when Sforza expressed some impatience, da Vinci actually scrapped the model he had made because he was dissatisfied with it. He then began all over again, and this work engaged him for another three years. In 1493 a model horse twenty-six feet high was put on view in the courtyard of the Castello Sforzesco, and it remained there for several years. Contemporary accounts testify to its magnificence. Yet it was still not cast in bronze by the year 1499 when war took da Vinci away. His patron was eventually defeated by Louis XII and during the sack of Milan in 1500 the statue was used as a butt by Gascon archers. Despite requests from noble Italians to possess even the damaged remnant, it was eventually broken up and today not even a broken limb remains for anyone to see.

The long delay in the execution of this statue is puzzling—as puzzling as the smile of the Mona Lisa! Even if the accident of war is ignored—and it interfered only after 1499—there still remains the period of sixteen years from 1483 to 1499, of which ten passed before the model was ready. The artist during this period executed paintings that have survived, including the famous Last Supper, painted in tempera on the wall of the refectory of the convent church of Santa Maria delle Grazie at Milan. Nevertheless, the period is a long one and ought to have been the most creative of da Vinci's life—from the age of thirty-one to his forty-eighth year. He took four years over the painting of the Last Supper, so the model for the equestrian statue could have been done in a similar time. But he was all the time being asked to dissipate his energies in many different ways. His eloquence and charm made him more or less the director of all court festivities, of which there were plenty, and his recorded activities of this sort include the mechanics of a masque of paradise, the design of a bathing pavilion for the young duchess, and the inventions of jests and fables and allegories. Moreover, in 1498 he was called on to carry out his duties as chief military engineer.

A further distraction remains to be mentioned. Leonardo da Vinci was a natural scientist. During the whole period he was meeting eminent savants and filling notebooks with sketches and notes on science and invention.*

* These notes were in mirror-writing, which suggests that da Vinci was purposely making it difficult for other people to read them. This subterfuge is reminiscent of the way Pepys wrote his diary in shorthand.

Some two hundred of these sketches are exhibited in fascimile at Burlington House. The surviving notes exist in the Codice Atlantico at Milan and Manuscripts A and B in Paris (part of the Napoleonic loot from Italy) and in private manuscripts such as the Leicester Codex, which is in the present exhibition. The wealth of material in these notes is overwhelming. The Leicester Codex is entirely concerned with hydrostatics, which is most remarkable in that the work of Archimedes was then lost in oblivion and not published until 1565, though there is little doubt that in the intellectual revival of the twelfth and thirteenth centuries the works of both Euclid and Archimedes had been rediscovered, and at least part of their work was kept alive either verbally or in manuscript by savants in the universities.

Other notes which are exhibited refer to machines, though it is not always possible to say whether da Vinci was the actual inventor of the machines described, or merely the man who recorded or perhaps developed another's ideas. There seems to be no doubt that da Vinci was the first inventor of the parachute, for instance, and at the Science Museum one can see the model parachute which the museum's staff have reconstructed from his notes. He dallied with flying machines, which he modelled on flying birds, just as Mitchell ("The First of the Few") modelled the 'plane he called the Spitfire on sea-birds. Many of the sketches and notes are in the nature of projects rather than inventions carried through to a practical conclusion. This applies to his plan for a screw-cutting machine: here one finds that a machine made exactly as he designed it would have turned a thread going in the opposite direction to that which he evidently intended. The Science Museum has made a model of this screw-cutting machine, as well as of several other da Vinci projects. Almost without doubt he was the first inventor of such a machine, and the machine he designed would have worked, as the model demonstrates effectively. Other sketches show hygrometers based on the absorption of moisture by cotton, an anemometer depending on the deflection of a hinged plate (probably the earliest record of such an instrument) and a towable rotating ship's log "for reckoning the mileage of the sea". Still other sketches show apparatus for grinding mirrors, both plane and spherical. In other words, Leonardo da Vinci's interests covered mathematics, mechanics, hydrostatics, optics and meteorology, as well as the arts of war.

One further illustration of his scientific interests provides a clue to the man's nature. It lies in the realm of anatomy and physiology. The action of the heart, the formation of the brain, the physiology of vision, all were studied with immense application. Da Vinci was a man of compelling curiosity about the whole world around him, not only in its superficial aspects but in the underlying springs of form and action. As Sidney Colvin wrote of him in the eleventh edition of *Encyclopaedia Britannica*: "Every fresh artistic problem immediately became for him a far-reaching scientific problem as well. The laws of light and shade, the laws of 'perspective', including optics and the physiology of the eye, the laws of human and animal anatomy and muscular movement, those of the growth and structure of plants and of the powers and properties of matter, all these and much more furnished food almost from the beginning to his insatiable spirit of enquiry."

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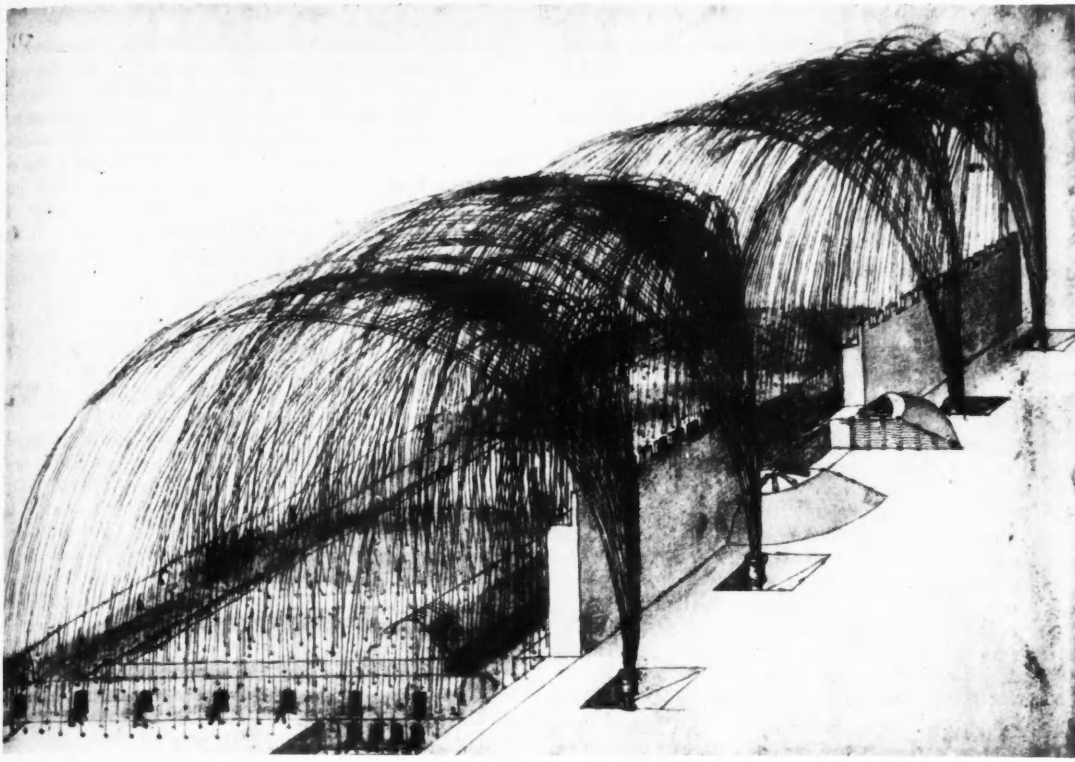


Five centuries ago Leonardo da Vinci was born—on April 15, 1452, to be exact—in a small single-storey house in Anchiano. Italy celebrated the centenary with a ceremony in that town which was attended by the Italian President, Signor De Gasperi, and many foreign diplomats. A tribute to Leonardo's versatile and universal genius was paid by the Director-General of Unesco, Dr. Torres Bodet, who stressed that in this great artist-scientist the painter, the sculptor, the architect, the physicist, the naturalist and the philosopher could hardly be considered apart from one another.

In Britain, da Vinci exhibitions have been organised at the Royal Academy and the Science Museum. All over the world the anniversary has been celebrated; Unesco has helped in this connexion by distributing many sets of facsimile reproductions of his drawings.

The three pictures here reproduced epitomise his career as a creative artist and a probing scientist. The top picture, a plan for bombarding a city with mortar fire, illustrates his interest in military engineering. *Below (left)*: da Vinci's design for an aeroplane: note the mirror-writing underneath. (*Right*) A pen-and-ink drawing of wood anemone and marsh marigold, *c.* 1505. (*The first and third pictures are reproduced by gracious permission of H.M. the Queen.*)

In other words, da Vinci could create and apply scientific method to the investigation of the laws of his creation at the same time. He could not deny his nature. Had he lived long enough to complete the books he wished to make from his notes he would have achieved an integration, a wholeness, rarely achieved by anyone of small range, and still more rarely, if ever, by one of such high intelligence and wide range as Leonardo da Vinci.

Fuel Saving, Passport to Prosperity

In this issue and in the April issue, Professor Simon has studied the prospects for energy in the future. He has put his name to an impressive document which, in one respect, reminds us of our first passport. This began "We, John Simon . . ." and enjoined the world to give us all assistance in our travels. Travel in those days was hampered by a number of people, like Hitler, who did not want to assist, and there seem to be a number of similar obstacles in the way of Professor Simon.

With his technical arguments there can be no disagreement. With brilliant simplicity he has examined a wide range of possibilities and made complex questions clear.

In this month's article Professor Simon makes an assertion which is virtually the same as the one Dr. Bronowski made at last year's Smoke Abatement Conference. Dr. Bronowski said, in criticism of the Severn Barrage Scheme: "We talk grandly of harnessing the tides on the Severn at a cost of £100 millions; but half that sum would modernise enough house and factory grates to save 20 million tons of coal a year." Professor Simon makes just the same sort of criticism; referring to the same project, he writes: "When we consider that with half the capital investment [i.e. £50 million] 20 million tons of coal could be saved per year by improving heating appliances in Great Britain, it is obvious that such a scheme has no attractions." We regret that a note of disagreement must be struck here, but we are left with no alternative since we find ourselves quite unconvinced that an immediate solution of Britain's fuel and power problems can be found in the proposition that all that is necessary is to install better heating appliances. The first ground of objection is a purely instinctive reaction. To have a promised annual direct saving of approximately £100 million for an investment of £50 million is so brilliant a financial offer that the lack of takers is difficult to understand; to criticise it is surely to look a gift horse in the mouth! When to the direct saving are added all the other advantages of a further available 20 million tons of coal —the escape from a permanent fuel crisis, an invaluable export, and a prop to foreign policy—the neglect of such an offer must seem unpardonable, especially since it is Britain's economic existence which is at stake if a satisfactory solution of the fuel and power crisis is not accepted and implemented.

Professor Simon and Dr. Bronowski both agree that £50 million spent on improved heating appliances will save us 20 million tons of coal *each year*. What we would now welcome is the publication and discussion of the detailed specifications and estimates on which this proposed saving is based. There cannot be many domestic fires involved in the scheme because £50 million goes practically nowhere when divided between millions of houses, as we pointed out in the November 1951 issue (p. 340). More economical stoves, grates and boilers may be installed in new houses, but the annual rate of new building accounts for only a fraction of the houses which use fuel. Any conversion or modernisation programme, in the home or industry, cannot usually be carried out on the cheap. To throw out a wasteful water boiler—the sort which has poor air-control, no easy means of removing ash, and an unequalled power of self-extinction—is an easy decision, but to replace it by a fire with back-boiler or an insulated rocking-grate, thermostatically controlled job costs from £30 to £60, depending on the type, the amount of replumbing and new flues involved. With luck this may save 1 to 2 tons of fuel per year. Here one sees that there can be nothing like the £2 10*s*. investment per ton of coal saved, which is the figure quoted by Professor Simon and Dr. Bronowski.

On the larger scale of, for instance, the small works with an office block attached, the desired ratio again cannot be reached. Let us quote the case of a factory we know; this factory with steam-operated prime-movers coupled the exhausts to supply low-pressure steam in the way it is suggested power stations could operate. In spite of a short distance in this case for the mains, an installation which saved 20 tons of coal a year cost £1000 to install. No more equipment was required than for any of the district-heating schemes suggested—this factory put in calorifiers, a water-circulating pump, and radiators in 24 rooms. In this case, much greater *comfort* has been obtained than was possible with coal fires, but the scheme could be justified only on that basis, and not on any consideration of the period required to pay off the plant. It may be that larger-scale working would show figures nearer to the £2 10*s*. per ton ratio. We have in mind the Pimlico housing scheme of the City of Westminster. Many Londoners will be familiar with the tall glass structure which encloses the water storage tank by the Embankment; Battersea power station on the other side of the river supplies the exhaust steam on which it operates a central-heating installation. Figures on the running costs, compared with the costs estimated (we believe) by Messrs. Kennedy and Donkin, should now be available for the period of a year or so that the scheme has worked, and they would be of great interest. The clouds of steam from power-station cooling towers represent a great challenge, as Professor Simon has demonstrated, but his own words on power costs in this connexion seem to apply just as well to any proposal to use exhaust steam for heating. "We cannot expect any spectacular changes in the *price of power* owing to the development of new sources of fuel. Only a small part of the price the consumer has to pay for energy is due to the cost of the fuel (roughly about one-sixth in the case of electricity produced by burning coal). The rest goes towards the cost of the power station and, in particular, the distribution system. The coal-fired power station has reached a high degree of perfection, and it is difficult to see how the generating plant for any other form of power could cost appreciably less. It is clear, therefore, that even if we were to find a fuel which costs nothing, there would be no spectacular drop in the cost of energy to the consumer."

Substitute 'heat' for 'energy' in the quotation and our point is supported. We agree that fuel saving is possible: our only quarrel is with the estimated cost.

The Coming of Heredity

C. D. DARLINGTON, F.R.S.

Director, John Innes Horticultural Institution, Bayfordbury, Herts.

We are all familiar with the idea, and some of us have experience of the fact, that a parent may bequeath to us a piece of land, or a gold watch, or some other material possession. This we call *inheritance*, and the process of bequeathing and inheriting property has been known among men for 10,000–100,000 years. But the name inheritance is also applied to another idea. We speak of the inheritance of our *own* biological characters, and this concept of heredity is an altogether newer idea than the simple concept of material bequests.

It was indeed less than a hundred years ago that Herbert Spencer had the good sense to use a distinct word—the word 'heredity'—for *the property of inheritance in living things*. This word, for the first time, distinguished the biological from the legal process. Associated with the use of the term *heredity* was the first glimmering of the idea that the way in which plants and animals inherited particular characters was governed by some natural laws.

Previously men had been apt to be confused when they discussed the question of heredity. Early views about heredity had been expressed with force but even thinkers like Aristotle or the Ionian philosophers who discussed these matters in writing did not succeed in making their views hang together.

The same applies to the ideas about heredity expressed by the Old Testament prophets who in this, as in other respects, are most emphatic in their opinions. To Moses it was evident that the sins of the fathers should be, and would be, visited on their children and likewise on their grandchildren. But, later, to Ezekiel and Jeremiah, the inheritance of the effects of sin was by no means a foregone conclusion.

In ancient times, practical breeders as well as prophets were interested in these things. Stockbreeders were eager to make use of any trick that came to their knowledge; and the tricks they used show that it was the older idea of Moses that they subscribed to. In the Book of Genesis, Jacob tells us exactly how it works. He shows how he can make the ewes bear striped lambs by giving them a glimpse of striped bark. He has to show it to them (so he says) at the moment they are being tupped. He believes that a sharp impression on the mind of the mother, albeit not a highly imaginative mother, will break the colour of the newly begotten lamb. Practical folk have nearly always held views of this sort. Typical of such beliefs is the idea held by Dickens's Mrs. Gamp and millions of other mothers that the impression of some shocking sight seen by a pregnant woman will leave its mark on the body of the child.

Philosophers and cultivators of the soil have thought long and deeply about the way the heredity of plants is affected. For instance, two thousand years ago Theophrastus said that manure and cultivation convert the unimproved wild olive plant into the heavy-yielding tree of the garden. Even today many practical gardeners believe the same. It seems so obvious and it explains so much.

Yet, when you think about it, how does it work?

If you believe such things, other questions, other difficulties arise. When you have married a widow, will the children bear some influence of her first husband? With many cattle-breeders in our own country this seems to be obviously true; at least it appears to explain a great deal.

Aristotle has a lot to say about it. To explain such things, people had repeated what must surely be the oldest of all biological theories, the common-sense theory, the *direct* theory of heredity. It was that the parent is represented in his (or her) entirety in the seed or germ. The seed or germ is a model into which the parent is condensed in all his parts. *Messengers* from every organ are gathered into the seed representing the whole body. So that when the offspring grows up, it shows the characters of the parent in their full development, as they were when the offspring was begotten. But Aristotle did not like this theory. It probably sounded too crude and materialistic. And he points out that a seed may grow into a plant bearing a fruit, such as a plum or an apple, like that of the parent. Yet the seed was itself formed before the fruit that bore it became ripe. How then could some messengers have carried the character of the fruit into the seed?

The point was well made and the problem remained to tantalise inquiring men. Long, long after Aristotle, we hear the French philosopher, Montaigne, remarking that his father suffered from the stone, and that *he* himself suffers from the stone. He must have inherited this weakness from his father. And yet his father developed the stone a good seventeen years after having begotten the young Montaigne! How could such a mere potentiality be determined, determined at a great distance of time, and determined just by a drop of fluid, the drop of semen which is his only material connexion with his father?

To thoughtful men the direct theory of heredity presented as many problems as it solved. But those who wanted a quick solution have always accepted it. When, at the end of the eighteenth century, a theory was needed to explain how plants and animals had become diversified in the course of descent from simple common ancestors—by the process that we now call *evolution*—then naturalists promptly assumed direct inheritance. They had no compunctions about their assumptions. They took it for granted, without troubling about little philosophic difficulties, that the entire characters acquired by each individual during life are directly handed down to his offspring. This is how the angry stag has grown his horns, said the French evolutionist, Lamarck. And equally the hungry giraffe, by stretching his neck to eat the leaves of the palm trees, has grown to be the tallest of animals. Darwin, in his turn, thought he could not do without the hypothesis of messengers—he christened it *pangenesis*—according to which there are messengers of heredity to carry acquired characters to the seed. And, in our time, the Russian Lysenko, unconcerned about discovering the past but deeply concerned about controlling the future, and

believing that bad environmental conditions will, by themselves, turn one species into another—wheat into rye—has written a book to show how it happens.

It is not impossible for us to believe these things so long as we see the processes of reproduction only with the naked eye. Aristotle or Montaigne might well believe that the semen was merely fluid; and that it did its work as a vapour, the *aura seminalis*. So long as men trusted to their eyes alone it was very natural for them to think that the reproductive effects arose through the 'prolifick virtue' of the semen of animals or of the 'spermatick globulets' (the pollen, as we now call it) of plants. The belief that *humours* and *essences* and *principles* were the agents of all natural processes is the common-sense view and the naked-eye view. And it exists almost everywhere today except among those who are accustomed to using powerful microscopes.

When we use high magnifying powers, multiplying an area by a million, we find something very unexpected. We find that the complicated structures seen in living things with the naked eye become, not *less* complicated, but *more* so, under the microscope. We do not find that the patterns become simpler by enlargement. Quite the reverse. They reveal a new and unforeseen order of organisation. Instead of the translucent fluid of the semen we see a world of animalcules. We see the spermatozoa. Instead of the yellow powder of the pollen we find a mass of grains, each one looking as large, as creased and as furrowed as a man's hand. And within each one sees a globular body, the *nucleus*. And within the nucleus there are threads, protein strings, strings of reproductive materials—the *chromosomes*, as we call them, that govern the life of the pollen grain, and of all other cells that go to make up the bodies of plants and animals.

With the microscope we are able to penetrate into a new world, a world of small particles. A world of cells and nuclei and chromosomes. These are not fluids or humours, principles or essences; they are solid bodies, and it is these bodies that carry whatever is responsible for heredity.

Now Lamarck did not accept the view that heredity was carried by the sperm or pollen at all. He thought it all came through the egg, through the female. And Darwin did not accept the view that animals and plants were simply made up of cells; in fact, Darwin was still by no means free from the idea of vital principles and humours. Neither Lamarck nor Darwin could ever think in terms of what one sees through a microscope; neither, therefore, could ever think of heredity as we think of it today, in terms of particles of matter.

The new idea of cells first struck the imagination of the scientific world a little over a hundred years ago—in 1840. It transformed the outlook of the younger generation. The old idea that animals and plants behaved as they did because their humours and essences were balanced to fulfil the harmony of nature, in accordance with a divine purpose, gave place to an opposite view; in fact to *the* opposite view, that they were composed of material particles which had to behave as they did because they were *made* like that. It gave place to the view that the character of a living creature might be determined by its material composition and structure, a composition and structure which might be tested by experiment, and seen under the microscope.

Gregor Mendel (1822–84). He discovered the basic principles of genetics, yet his findings were ignored for thirty-five years.

Mendel's 'Lost' Paper

So it was that the principles of heredity came to be discovered at this time, by one man, and at one stroke. It was the Austrian monk, Gregor Mendel, a man experienced in the use of the microscope, who in 1865 showed the three great properties of heredity.

These properties conflicted so entirely with popular belief that they have never been fully understood even to this day. At least that is my view.

What are these properties? Mendel's method was to breed plants experimentally. He showed that, if you cross two pure-breeding varieties of peas, the offspring are uniform. And they may resemble the mother plant in one respect, the father in another. But when these offspring, *hybrids* as Mendel called them, are themselves bred together, they produce progeny which are not uniform. They show all possible recombinations of the characters of the grandparents. That is, what is lost or latent in the first generation reappears unchanged, but in new combinations, in the second generation.

The conclusions that Mendel drew from this experiment were sensational. Something, he said, must *determine* the character of each plant in each respect. This *something* must be handed down from generation to generation. It must be *double* in each plant, one element coming from each parent, the two corresponding elements being separated when the germ cells are formed. In a hybrid, only one element, the dominant partner, expresses itself, while the other, the recessive, is hidden. But neither element can be changed, or impaired, by living, as it does, in every cell along with its partner. The recessive element cannot even be changed by the character of the plant it is living in. And these principles, if they were to apply at all, were bound to apply to all plants and animals and to ourselves.

To express all this in one word: heredity is *indirect*. Mendel's elements are determinants, determinants which are handed down from generation to generation. They determine the character of the plant or animal. But the reaction is *not* reciprocal. The character of the plant or

Most scientists regard the characters of living organisms as being the products of the interaction of environmental and hereditary factors. But from time to time there arise schools of thought that overstress the part played by environment and so revive the misconception of the Lamarckian creed; the latest exponent of this type of 'theory' is ex-physiologist Trofim Lysenko (here seen demonstrating to visitors to an All-Union Agricultural Exhibition in Moscow), who won a Stalin prize in 1948 "for scientific research in the sphere of advanced Michurin Biological Science".

animal has no effect whatever on the determinants present in its cells, no effect on its heredity.

No one took any notice of Mendel's paper. As is well known, it lay unread in the libraries of Berlin and Paris, of London and Manchester, for thirty-five years, until 1900. But it was during those thirty-five years that the behaviour of the chromosomes was worked out. And their properties were shown to meet the needs of the very determinants of heredity that Mendel had, shall we say, discovered or invented.

Experimenters, after 1900, were fascinated by the methods that Mendel had used to prove that his determinants really were determinants, and really did recombine. Indeed, they were so fascinated by the ratios of recombination, which they found in their breeding progenies, that they overlooked the great principle of determination itself. They were unable to see the wood for trees, a not uncommon feature of scientific work. They thought the essence of Mendelism was *chance*: the chance of recombination. Indeed it is this chance which gives the pattern and diversity to our lives, which makes children differ from their parents, and which makes brothers and sisters differ from one another. But the chance is merely an incident in the life of the elements which are recombined. The character of these elements (which we now call *genes*) depends on their capacity for determining, not merely the *likeness*, but also, strange though it may seem at first glance, the *unlikeness* of parent and offspring. For it is the assortment of genes which determine the whole development, the whole life, of the individual. In a word, it determines his *individuality*.

"Stop!" I can imagine the cautious reader saying to himself; "this is going altogether too far. Far beyond the evidence. We may admit that outside things, the circumambient conditions, do not leave their mark on heredity. But they undoubtedly impress themselves on the individual. Especially the human individual. We men are plastic, adaptable, educable. If we are given a fair chance we can achieve great things. No one shall shut the gates of hope on striving humanity with such a sentence of predestination! By our free wills can we not mould material things, and subdue the world, to our desires?"

These are great questions, which raise great objections to the gene theory. But they may be within the range of experimental inquiry. The experiments concerned are, we shall find, the most momentous that have so far been broached in the study of life. Man, of course, is not an animal that we can experiment with. But Nature, by a marvellous chance, is herself constantly making experiments with man, millions of experiments, which give us the answers we want to know. The experiments are concerned with *twins*.

Research on Twins

It is a proverbial observation that twins are more like one another than are brothers and sisters born at different births. What is the explanation? To Darwin it seemed enough to say that outside conditions were here making themselves felt before birth. Brethren of different births were subject to different conditions. In the same womb together twins were subject to the same conditions.

But this would hardly account for twins being preponderantly of the same sex. Fifty per cent of twins should be

either both boys *or* both girls. In this country about sixty per cent of twins are of the same sex. Why is this?

An explanation was advanced by Darwin's enterprising younger cousin, Francis Galton, who by coincidence was born in the same year as Mendel, and who proposed ideas which were as far in advance of popular opinion as were those of Mendel. On both of them the influence of the cell theory and the way of thinking in terms of particles and units had made itself felt. Twins, said Galton, are of two kinds. The one kind, accounting for three-quarters of all twins in England, are derived from *two* eggs. These two eggs are released by the ovaries at the same time; they are separately fertilised by two spermatozoa; and they are separately implanted in the wall of the womb to produce two embryos. These are *two*-egg twins, and they are related like ordinary brothers and sisters—no more, no less; they are therefore of opposite sex just as often as they are of the same sex.

The other kind, of which there are probably only a quarter of a million in this country, are derived from *one* egg fertilised by *one* sperm. This single egg begins to undergo division to form a mulberry-shaped mass of cells, but then this embryo splits into two separate embryos which grow into two one-egg twins. Are these *identical* twins? Sometimes the twins are identical; but this is not always so for, if the split takes place late, and a single afterbirth is formed, the *lopsidedness* of the body—the heart being on one side, and so on—may have made itself felt. The two twins may then be made somewhat different, even different in the obvious respect of weight at birth.

What is identical for one-egg twins is *the nuclei with their chromosomes*, derived from the fusion of the nuclei of the parent egg and sperm. These endow the twins with an heredity as near to identical as nature can arrange. But the rest of what the twins receive—the protoplasm, the ground jelly of the egg in which the nuclei move and work—is somewhat different. The lopsidedness of the egg is due to a lopsidedness in this jelly. And in this respect, therefore, one-egg twins are actually less alike than other twins, less alike even than ordinary brothers and sisters.

The characteristics of one-egg twins agree very well with what this origin would lead us to expect. They often differ at birth and occasionally differences, for example in temperament, persist for many years. But, so far from the one-egg twins growing less alike—that is, *diverging*—as two-egg twins do, as a rule they *converge*, growing more and more alike. The nucleus and the chromosomes in respect of which they are identical, gradually bring the ground jelly under control and establish the identical genetic character of the two individuals.

The physical resemblance of one-egg twins is, of course, always striking and sometimes staggering. But it goes far beyond anything that is seen by the naked eye. Between ordinary brothers or sisters it is impossible to graft skin: it merely sloughs off. Between one-egg twins skin grafts always take, which means that even the protein molecules of their cells, being derived from the same egg, are alike. And they are unlike those of any other human beings.

It is this fundamental chemical identity on which the unique similarity of one-egg twins is founded. Everything else follows from it including, of course, similar susceptibility or resistance to all infectious diseases, similar blood groups, similar taste sensitivity. And ultimately, through the whole gamut of increasing complexity, they have a similar structure of the brain and similar capacities of the mind.

Many methods have been invented for testing the capacities of the human mind, yet none will ever be invented so thorough as the test provided by the social process as a whole. Education, health and crime are the three aspects of the social process most amply recorded and most sensitive to error.

Unfortunately records of the education and health of twins are still grossly neglected. But our knowledge of their relations with crime takes us to the root of the problem.

The study of one-egg twins carried out twenty years ago in Germany by Professor Lange, although I fear not at all well described, has shown that, where one twin has a criminal record, with few exceptions the other has also. Moreover, the type of crime is similar. The first occurrence of crime is at a similar age, even when the twins have been separated. The frequency of conviction is similar. But we have to allow for the fact that different judges may give different sentences for the same crime—for the judges are not usually one-egg twins—and a prison sentence stops further offences for the time being.

Indeed one may ask: is there anything else that will stop further offences? The German inquiry shows that there is one other circumstance that will stop a criminal career. It is if a weak-minded criminal man marries a strong-minded non-criminal wife.

No other evidence than the study of one-egg twins could so decisively prove the overpowering effect of heredity. But no other evidence could reveal the space that is left in the picture to be filled by the environment. What is this space? The answer is that the amount depends on the heredity. The strong heredity of the able, the energetic and the intelligent, so far from passively reacting with their environment, first *choose* their own environment; then they *change* it; and in due course they may change the environments of others and even the environments of succeeding generations. Their heredity does not float in the conditions that are given it, it creates the conditions for themselves, and for the world at large.

By inquiring into heredity we have found a power of determination which is (as it now appears) something vastly greater than what we were looking for. Let us not be embarrassed by the magnitude of our discovery—Mendel's discovery and Galton's discovery, and the discoveries of the microscope which make sense of them both.

I will now briefly show what they mean. Like Darwin's evolutionary theory of a hundred years ago, the new genetics represent a revolution in human thought. The two revolutions are of similar scope and gravity. Let us first look at the new world, as it were, through a microscope. All the spermatozoa which begot the living population of these islands could be contained in the space of one pin's head. Within twice that volume we could put the whole substance of the nation's heredity. That *amount of matter* determined what we are, and what we may be. Nor is it just for a few months, or a few years, but for the whole of our lives, and down to the casual gesture and the susceptibility to accidental infection sixty, seventy or eighty years

ahead. And, subject to the laws of chromosome and gene behaviour, the future generations of our race are likewise determined in their character by these potent pin-heads of 1200 million chromosomes.

Our increased belief in the accuracy of the predictions of biology (for so we must look upon it) is all the more notable because it has come at the same time as a *decreased* belief in the accuracy of the predictions of physics. But we must remember that the total capacity for prediction in both branches of science is continually increasing.

This is the inside *of the question. The* outside *is made of more practical matters. If ever the practical experts and the theoreticians succeed in getting together (and this is made extremely difficult by vested interests and by the artificial specialisation and compartmentalisation of the scientific world), then it may one day become possible to reach a genuine understanding of the biology of man and of all other living creatures. At present biology, like mankind, is kept split apart by the different orthodox theories, including official Catholicism, Liberalism and Marxism.*

When all these separatist creeds eventually come together and finally dissolve their differences (by neutralisation of mutual 'acidity' and 'alkalinity')—and those differences are so much more obvious than they are real—a true science of biology will be able to emerge. This science will go much farther than the mere dissection of dead animals and plants, the analysis of results obtained from unnatural experiments and the systematic classification of dried and bottled specimens that clutter up the vaults of National Museums of Natural History scattered all over the world. At that stage biologists will be ready to eliminate those differences which are calculated to separate their particular and limited specialism from other specialisms. Biology would acquire its mantle of life and it would then be ready to take its proper place in the evergreen field of natural knowledge: and at that stage all nature will become one, as children and wise old men of all ages have always known, without even bothering to think about it.

ELECTRIC WHALING

DESPITE long experience in hunting, little exact knowledge has been accumulated over the years on whales and whaling; the paucity of precise data and experimental conclusions has rendered it most difficult to develop and apply a safe method of electric whaling. Yet increased efficiency in catching remains of the utmost importance. From the humane aspect, the firing of several explosive harpoons into a dumb mammal, which may fight in agony for up to two hours, is highly undesirable to say the least. From the commercial point of view, the use of whale oil and other products is so widespread that it is important to take full advantage of every opportunity to lower the costs of catching, and to improve the quality of whale products.

The Svend Foyn heavy harpoon was introduced in 1865 and has been little altered up to the present day. Electric harpooning was first recorded in London in 1868, when a patent for electrical equipment was granted, but no practical results of any experiments are known. There followed two Norwegian experiments, but the first promise of some success came in 1929, when Dr. Webber, a German engineer, succeeded in electrocuting four fin-whales off the Norwegian coast. Further experiments, including the reported electrocution of 250 whales in 1932–3 by the Sir James Clarke Ross Fleet, were carried out in co-operation with Dr. Webber until 1945, when he destroyed all his papers on committing suicide. Post-war research and new design have been continuously carried on for the last five years by the General Electric Company Ltd. of England, in close co-operation with the British whaling company of United Whalers Ltd., and in conjunction with Elektrohval of Oslo.

Renewed impetus was given to this research upon the return from the Antarctic of Dr. Lillie in 1947, when he described explosive harpooning to members of the Universities Federation for Animal Welfare, who strongly advocated a thorough investigation of possible, more humane, methods. These investigations indicated the electrical method of killing as the most promising solution. This was supported by the Directors of United Whalers Ltd., who undertook the extremely heavy costs of commissioning an experimental catcher to collect data during the 1948–9 Antarctic season. The fact that this costs some hundreds of pounds per week emphasises both the generous response of United Whalers Ltd., and the importance they attach to the matter.

The whale-catcher *Terje 2* was hurriedly equipped for the Antarctic. Complete heavy, waterproof, control equipment was built, with a 250-volt, single-phase alternator; electric manila forerunners (the lines to which the harpoons are attached) were made up, and the Konsberg Gun Company of Norway sent an experienced technician to assist.

Three major difficulties were revealed. First, the gear received such an enormous buffeting when mounted in the bow, ploughing through high seas and icing up in snow and gales that the equipment demanded too much attention. Second, the harpoon was deflected in flight by the trailing of the electric manila forerunner, and by the heavy tubular sheathing on the leg of the standard harpoon, by which this was insulated from possible short-circuiting with the sea. Third, many post-war gunners had adopted nylon forerunners, which suited Antarctic conditions better than manila; particularly as the latter absorbed a much greater percentage of sea-water than does nylon.

In agreement with United Whalers Ltd., the G.E.C. redesigned the master control panel, to be housed in a miniature marine enclosure and mounted on the bridge for convenient control by the helmsman or other appointed operator. In Norway, Elektrohval and the Konsberg Gun Company made a clean break with the adapted forms of Svend Foyn harpoon and produced an entirely fresh design. Unencumbered with the heavy insulating tube, this is now well known as the 'detachable leg' type harpoon: the flow of current into the sea is prevented by withdrawing the shaft of the harpoon when the head and forerunner have become fast to the whale. Simultaneously the

Pirelli-General Cable Works, in close co-operation with British Ropes Ltd., had to solve the problem of designing a flexible electrical conductor to be carried by the three-cordal rope and to meet the inherent characteristics of the nylon, which can expand and contract by 40–45% according to the pull of the forerunner.

In considering the effects upon the whale itself, it was learnt that the flow of current with any satisfactory shot produced immediate paralysis, the whale surfacing with no struggle. The convulsion of the tail flukes (which can measure up to 24 ft. from tip to tip) acted as a brake upon the movement of the huge body and, turning over on its side, the whale was dead within three minutes from the firing of the shot.

The Directors of United Whalers Ltd. next decided to commission a second catcher for the Antarctic season 1949–50, in order to ascertain some idea of critical buoyancy, load figures, stresses, short-circuit conditions, time of flight of the harpoon and the effects of Antarctic sea conditions. One of the initial problems to be determined was the critical buoyancy of the whale's body, so Messrs. Westley Richards and Co. Ltd. of Birmingham produced a spigot gun to fire a very light-weight harpoon. Again, the Pirelli-General Cable Works had to construct an ultra-light-weight conductor of very high tensile strength, together with the necessary mechanical apparatus to feed out this conductor at the higher operational velocity of the spigot gun.

Sir Vyvyan Board, a director of United Whalers Ltd., decided to join the expedition at Cape Town and travelled 15,000 miles in the whale-catcher round the Antarctic continent to the Ross Sea area, accompanied throughout by Mr. Robert Marsden of the G.E.C. In addition, Mr. Dagfinn Bröther of the Elektrohval Company with Mr. Venaas of the Konsberg Gun Factory carried out successful electric killing with the standard Konsberg gun. Westley Richards Ltd. were represented in these trials by Mr. Roy Hill, who, having helped to build the experimental spigot gun, serviced this in the severe climatic conditions of the trials. Once in the Antarctic, the effects of low temperatures and icing up were soon manifest. Elementary manipulations of the gear took longer to perform than in warmer climates owing to the heavy clothing and bitter weather. Obvious, too, became the practical difficulties of recording observations when the crew were working watches in such conditions. An instance was provided, moreover, of the snapping of the light harpoon, made of high-tensile steel, by the convulsive movement of the whale's dorsal muscles; thus the conductor was parted by the enormous strength of these muscles and the whale regained consciousness, ultimately swimming away and taking part of the harpoon with it. In the end the expedition returned from the Antarctic with much vital information of the behaviour of various species of whale, the electric current required, time duration and so on, and with a catch of 51 whales by the Konsberg gun.

Attention was then directed to the outstanding problem of the stresses and strains imposed upon the mechanical whaling equipment. Instead of waiting for the forthcoming Antarctic season, the Directors of United Whalers Ltd. arranged for a trial expedition to the little island of Sao Thome on the Equator off the African coast. A whale of the Sei species, weighing 50 tons, was quickly killed and, after various tests in which the mammal sank to approximately 300 ft., it was safely retrieved and hauled in on a new type of forerunner, which the Pirelli-General Cable Works had produced on a new principle with a tensile strength of little more than half that normally used. Based on this initial success, further experiments are contemplated with an improved spigot gun, still using a lighter harpoon than normal.

This story of endeavour for a much-needed, more humane and more efficient system of whaling could not have reached this stage without the generous support of United Whalers Ltd. It may now be said that the whale can be killed without any undue pain and with less waste of whale products. The average time for the shooting, killing and tying up of a whale is considerably reduced with the electrical method; fewer electric harpoons are used and the consequent overall saving in time, materials and products will represent a substantial financial gain to the whaling industry.

Pepys was a man of many parts. Popularly known only as a gay philanderer, that role cloaks his true worth as a civil servant and shrewd man of affairs. His services to the Navy are generally underestimated, though his contribution to the restoration of the Navy as Britain's first line of defence was most important; one finds him described in an Admiralty minute written in the year of the Battle of Trafalgar as "a man of extraordinary knowledge, of great talent and of most indefatigable industry". His connexion with science is even less appreciated, though he was a President of the Royal Society whose imprint appeared on the first page of Newton's *Principia*.

Samuel Pepys, F.R.S. (1633-1703)

DOUGLAS McKIE, D.Sc., Ph.D.

In the early days of the Royal Society of London, scientific attainment was not a necessary qualification for election to its Fellowship or even for promotion to the office of President; candidates for membership had merely to be interested in the 'new philosophy', that is in the new way of studying Nature and her mechanism by experiment, and, of course, acceptable to those who were already Fellows. Thus, while the roll of Past Presidents includes for the seventeenth century names that are famous in the annals of scientific history, such as those of Wren and the incomparable Newton, it bears also that of Samuel Pepys. Although usually known to an almost distant posterity as the compiler of a remarkable diary, a reputation which by the nature of things he could not have acquired among his contemporaries, Pepys in his own age won high and well-deserved respect for his outstanding services in the organisation of the Fleet in times of great national peril; and the diarist known to a later age has tended to obscure the superb administrator who was justly regarded in his own time as the saviour of the Navy.

Samuel Pepys was the fifth child of John Pepys, a London tailor, and his wife, Margaret Kite, the sister of a Whitechapel butcher.* The Pepys family had a long history; they had originally been villeins in the county of Cambridge and through the later centuries of the Middle Ages they had risen to administrative offices in the ancient Abbey of Crowland; after the Dissolution of the Monasteries in 1539, they appear as landowners at Cottenham, whence in more recent times they derived their noble title. But in the seventeenth century, the younger sons of such rising families had often to turn to trade; hence John Pepys had left Cottenham in 1615 at the age of fourteen to become a tailor's apprentice in London and had eventually set up in business for himself and married in 1625 at the age of twenty-four. And, in Blackfriars, in the room above his tailor's shop, his fifth son, Samuel, was born on February 23, 1633.

Samuel first went to school at Huntingdon for a short time and then entered St. Paul's, still in its ancient home in the City. He went up to Cambridge in 1650, first, it is said, to Trinity Hall, but removing almost immediately to Magdalene College. Little is known of his life at Cambridge; he graduated B.A. in 1653; and his later life shows that he had the usual stock of classical learning and a love of all fine literature. In 1655 he married Elizabeth St. Michel, aged fifteen, daughter of a Huguenot refugee, Alexander Marchant, a gentleman of good family and poor fortune. Treated with sympathy and kindness after this rash marriage by his kinsman, Sir Edward Montagu, his father's first cousin and afterwards Earl of Sandwich, who invited the young couple to live in his house, Pepys was charged with superintending Montagu's household and attending to his affairs during the latter's absence with the Fleet. In 1658 he accompanied Montagu on a voyage to the Sound; later in that year he was appointed a clerk in the Exchequer to Sir George Downing, after whom Downing Street is named. For a short time he was one of the Clerks of the Council and then secretary to Montagu in the expedition concerned with the return of Charles II. After the Restoration, Pepys was given high office as 'clerk of the king's ships', or Clerk of the Acts, which was, in effect, secretary of the Navy Board, and which made him one of the chief officers of the Navy and gave him a rank equal to that of the other Commissioners. His diligence, his efficiency and his loyalty, demonstrated in the service of Montagu, had now brought him great place in the national administration. In 1660 he became Clerk of the Privy Seal and in 1665 Surveyor-General of the Victualling Office, where his zeal was soon apparent in the reform of abuses; finally, in 1673, he was appointed Secretary of the Admiralty, being replaced, however, in 1679 in a disgraceful persecution arising out of the 'Popish Plot', but recalled in 1684 and serving until the revolution of 1688 led to his retirement early in 1689. For almost a quarter of a century he had loyally served Charles II and James II; reference to his stupendous work as an Admiralty official will be made later.

* A plaque on the wall of the P.A.-Reuter building on the corner where Dorset Rise meets Fleet Street indicates the site of Pepys's birthplace.

Scientific References in the Diary

Meanwhile, Pepys had begun his great diary, which he kept assiduously from 1659 to 1669, abandoning it only when the worsening condition of his eyes brought upon him the fear of blindness. His election as a Fellow of the Royal Society dated back to February 15, 1665. Here we shall deal only with the references in his diary to the Royal Society and to Pepys's interest in its work and his attendance at its meetings. His later activities among his scientific contemporaries will be the subject of a further article. It appears that Pepys attended the meetings of the Society when his heavy official duties permitted, and that he was often disappointed when he could not be present. His entry into the Society came about in a curious way, as is made clear in the diary: on an official visit to Portsmouth in 1662, he was accompanied by Dr. Timothy Clarke, physician to Charles II and one of the original Fellows of

Viscount Brouncker (1620?–1684), who was appointed President of the Royal Society in its first charter (1662). A mathematician of repute, he had also studied natural philosophy and medicine at Oxford. In 1662 he was Chancellor to the Queen Consort, and also a Commissioner to the Navy. (*From the picture in the National Portrait Gallery.*)

the Society; thus he records on April 28: "The Doctor and I begun philosophy discourse exceeding pleasant. He offers to bring me into the college of virtuosoes [i.e. the Royal Society] and my Lord Brouncker's acquaintance, and to show me some anatomy, which makes me very glad; and I shall endeavour it when I come to London." Brouncker was the first President of the Society after its incorporation by Royal Charter in 1662 and held office from 1662 to 1677. (Sir Robert Moray was President before the granting of the Charter.)

For a time nothing seems to have come of Pepys's new interest: on February 1, 1664, in Whitehall, he records that "the King came and stayed an hour or two laughing at Sir W. Petty, who was there about his boat; and at Gresham College [the meeting-place of the Royal Society] in general; at which poor Petty was, I perceive, at some loss; but did argue discreetly, and bear the unreasonable follies of the King's objections and other bystanders with great discretion; and offered to take oddes against the King's best boates; but the King would not lay, but cried him down with words only. Gresham College he mightily laughed at, for spending time only in weighing of ayre, and doing nothing else since they sat." Charles II was, however, probably amusing himself at the expense of Petty, a prominent Fellow of the Royal Society and himself much given to such banter. Two months later, on April 14, 1664, Pepys was much interested in the account given to him by his colleague on the Navy Board, John Creed, who was already a Fellow of the Society: ". . . walked with Creed to the Coffee-house in Covent Garden, where no company, but he told me many fine experiments at Gresham College, and some demonstration that the heat and cold of the weather do rarify and condense the very body of glasse, as in a bolt head with cold water in it put into hot water, shall first by rarifying the glasse make the water sink, and then when the heat comes to the water makes that rise again, and then put into cold water makes the water by condensing the glass to rise, and then when the cold comes to the water makes it sink, which is very pretty and true, he saw it tried". The experiments had been shown by Robert Hooke at the Society's meeting held on April 6 and Pepys's entry is a good description.

The Virtuosi of Gresham College

On May 16, Timothy Clarke and Pierce, the surgeon, showed Pepys an experiment of killing a dog by an injection of opium into a vein, but this does not seem to have been a demonstration before the Society or connected with its work, although there are references at that time to similar experiments. Then, on October 5, Pepys met Henry Oldenburg: "So to the Coffee-house, and there fell in discourse with the Secretary of the Virtuosi of Gresham College, and had very fine discourse with him. He tells me of a new invented instrument to be tried before the College anon, and I intend to see it." The new instrument was the "Arched Viall", which Pepys saw later on that day, when "all the Gresham College" came to "the Musique-meeting at the Post-office"; he described it as "being tuned with lute strings, and played on with kees like an organ, a piece of parchment is always kept moving; and the strings, which by the kees are pressed down upon it, are grated in imitation of a bow, by the parchment; and so it is intended to resemble several vyalls played on with one bow, but so basely and harshly, that it will never do. But after three hours' stay it could not be fixed in tune; and so they were fain to go to some other musique of instruments".

Next year, on January 9, 1665, while Pepys was in the company of the Duke of York, he "saw the Royal Society bring their new book, wherein is nobly writ their charter and laws, and comes to be signed by the Duke as a Fellow; and all the Fellows' hands are to be entered there, and lie as a monument; and the King hath put his with the word Founder". Soon afterwards, Pepys was admitted to the Fellowship, entering in his diary on February 15, 1665: "Thence with Creed to Gresham College, where I had been by Mr. Povy the last week proposed to be admitted a member; and was this day admitted, by signing a book and being taken by the hand by the President, my Lord Brunkard, and some words of admittance said to me. But it was a most acceptable thing to hear their discourse, and see their experiments; which were this day upon the nature of fire, and how it goes out in a place where the ayre is not free, and sooner out where the ayre is exhausted, which they showed by an engine on purpose. After this being done, they to the Crowne Taverne, behind the 'Change, and there my Lord and most of the company to a club supper. . . . Above all, Mr. Boyle to-day was at the meeting, and above him Mr. Hooke, who is the most, and promises the least, of any man in the world that ever I saw. Here excellent

discourse till ten at night." Pepys had been to a memorable meeting; he had been admitted a Fellow; he had seen the experiments on combustion carried out in the receiver of the air-pump constructed for Boyle by Hooke in 1658–9 and called by Boyle his "New Pneumatical Engine"; and he had formed a shrewd opinion of Hooke. His next attendance was on February 22, but he recorded only "very noble discourse" without details of any experiments. On March 1, he went to a "second very curious lecture" at Gresham College by Hooke, which he describes as "about the late Comett; among other things proving very probably that this is the very same Comet, that appeared before in the year 1618, and that in such a time probably it will appear again, which is a very new opinion; but all will be in print".

After that lecture, Pepys went to the meeting of the Society: ". . . and this day I did pay my admission money, 40*s.* to the society. Here was very fine discourses and experiments, but I do lacke philosophy enough to understand them, and so cannot remember them. Among others, a very particular account of the making of the several sorts of bread in France, which is accounted the best place for bread in the world." The account to which Pepys refers was given by Evelyn and was entitled *Panificium; or the several manners of making bread in France, &c., where by general consent the best bread is eaten.* Pepys was again present on March 8, when he "saw several pretty experiments", and on March 15, when, after "the great poison of Maccassa" had been tried on a dog without any apparent effect, he himself made a communication to the Society of the report on the "pendulum watches" that had been taken by the master of a ship on the Guinea voyage; it had been claimed that these watches would enable mariners to determine longitude, and Sir Robert Moray expressed his approval of them, while Hooke roundly expressed his opinion that longitude could not be determined by them with certainty, and asserted that he had a secret for this which he would put into the hands of the President to be disposed of as the latter should think fit. Pepys, as an Admiralty official, was much interested in this problem; and, fittingly, towards the end of the meeting he "was desired to bespeak a man, at Deptford, for diving".

Then, on March 22, he attended again "and there did see a kitling killed almost quite, but that we could not quite kill her, with such a way; the ayre [being pumped] out of a receiver, wherein she was put, and then the ayre being let in upon her revives her immediately; nay, and this air is to be made by putting together a liquor and some body that ferments, the steam of that do do the work". According to Birch's *History of the Royal Society*, the 'air' admitted was produced by the action of *aqua fortis* [nitric acid] on pounded oyster-shells. When there arose a question of what this 'air' was and why it was supposed to be 'air', the President asserted that a body rarefied by heat and condensed by cold was 'air'; the members did not seem assured of this and it was suggested that a trial be made of the respirability of the 'air' used in a previous experiment and produced by the action of 'distilled vinegar' [acetic acid] on oyster-shells, and "the trial was made, and the bottle wherein that dissolution was performed, carried about to the members for every one to smell to it; and it was found by most of them incommodious, as it was so undiluted".

Samuel Pepys at the age of 34. The original of this portrait by John Hayls is in the National Portrait Gallery.

A mixture of acetic acid vapour and carbon dioxide would, one imagines, certainly be 'incommodious' in respiration!

On April 19, at another meeting, Pepys recorded: ". . . met Povy; and we to Gresham College, where we saw some experiments upon a hen, a dogg, and a cat, of the Florence poyson. The first it made for a time drunk, but it come to itself again quickly; the second it made vomitt mightily, but no other hurt. The third I did not stay to see the effect of it, being taken out by Povy." On May 3, Pepys being again present, some of these experiments were repeated; he went again on May 31, but "staid a very little while" and recorded no details of the meeting.

The Plague Year

London had now been stricken with plague, and on June 28 it was resolved to abandon further meetings until the President should decide to summon the members again. There followed a long interruption of nearly eight months, until February 1666. As for Pepys, while others left for the country, he remained at his post; almost the whole responsibility for naval affairs fell upon his shoulders; and he wrote to Coventry: "the sickness in general thickens round us, and particularly upon our neighbourhood. You, sir, took your turn of the sword; I must not, therefore, grudge to take mine of the pestilence." Again, during the Fire of London, he saved the Navy Office by his energetic action, ordering workmen to come from the dockyards at Woolwich and Deptford to pull down the neighbouring houses and so prevent the fire from spreading.

The next entry in the diary relating to the Royal Society is for February 21, 1666: ". . . with my Lord Bruncker to Gresham College, the first time after the sickness [the Great Plague of 1665] that I was there, and the second time they met. And here a good lecture of Mr. Hooke's about the trade of felt-making, very pretty." After the meeting he spent some time alone with Hooke discussing "the art of drawing pictures"; and Hooke told him that the best way was "like a dark roome [the *camera obscura*], which pleased me mightily". On April 11, Pepys recorded: ". . , after dinner to Gresham College, where a great deal of do and formality in chosing of the Council and Officers. I had three votes to be of the Council, who am but a stranger, nor expected any. So my Lord Bruncker being confirmed President I home. . . ." On November 28, he wrote: ". . . to Gresham College, where they meet now weekly again, and here they had good discourse how this late experiment of the dog, which is in perfect good health, may be improved for good uses to men, and other pretty things, and then broke up. . . ." In the "late experiment of the dog", blood was transfused on November 14 from a mastiff to a spaniel before the Society.

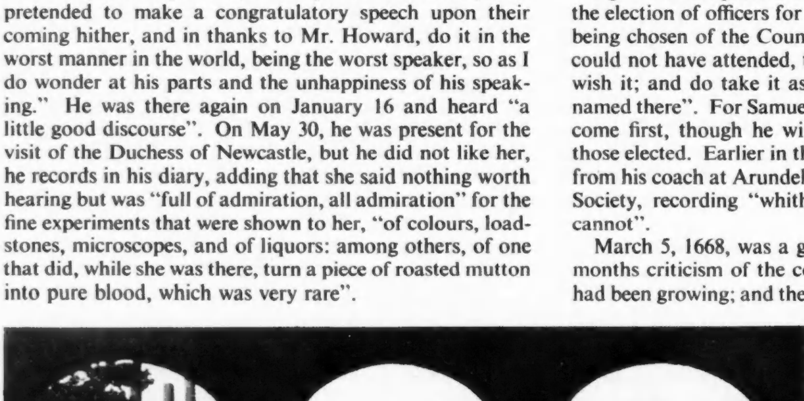
Pepys attended on January 9, 1667, the first meeting of the Society to be held in Arundel House, placed at the Society's disposal by Henry Howard, later Duke of Norfolk, a Fellow of the Society, their quarters in Gresham College being taken for other purposes after the Great Fire of 1666. Of this meeting, Pepys wrote: "Here was an experiment shown about improving the use of [gun-] powder for creating of force in winding up of springs and other uses of great worth. And here was a great meeting of worthy noble persons; but my Lord Bruncker, who pretended to make a congratulatory speech upon their coming hither, and in thanks to Mr. Howard, do it in the worst manner in the world, being the worst speaker, so as I do wonder at his parts and the unhappiness of his speaking." He was there again on January 16 and heard "a little good discourse". On May 30, he was present for the visit of the Duchess of Newcastle, but he did not like her, he records in his diary, adding that she said nothing worth hearing but was "full of admiration, all admiration" for the fine experiments that were shown to her, "of colours, loadstones, microscopes, and of liquors: among others, of one that did, while she was there, turn a piece of roasted mutton into pure blood, which was very rare".

On June 25, he made the entry: "I was told, yesterday, that Mr. Oldenburg, our Secretary at Gresham College, is put into the Tower, for writing newes to a virtuoso in France, with whom he constantly corresponds in philosophical matters; which makes it very unsafe at this time to write, or almost do any thing." Oldenburg had been imprisoned during the public alarm that followed the burning of British warships in the Medway by the Dutch, because he had criticised the conduct of the war in a letter that he had written to a foreign correspondent; he had given great offence to the King and he was not released until the Dutch war had come to its end some two months later; he had acted as a political agent in the collection of news for Lord Arlington, the Secretary of State, and for Arlington's secretary, Sir Joseph Williamson, and he had received much of the information for his political employers in the 'philosophical packet', the scientific 'diplomatic bag' in which foreign scientific correspondence was addressed to him as Secretary of the Royal Society.

On August 10, 1667, Pepys heard that Sprat's *History of the Royal Society* was about to be published; on the 16th, he saw a copy in his bookseller's and ordered "one in quires": he thought it "a fine book". On November 21, he arrived after the meeting of the Society had broken up, but he went to the tavern with some of his friends and heard of the hiring by the Society of Arthur Coga "for 20*s*. to have some of the blood of a sheep let into his body; and it is to be done on Saturday next". The talk in the tavern was "very fine", he wrote, "and if I should be put out of my office, I do take great content in the liberty I shall be at, of frequenting these gentlemen's company".

Again he was present on November 30 at a meeting for the election of officers for the next year, "where I was near being chosen of the Council, but am glad I was not, for I could not have attended, though, above all things, I could wish it; and do take it as a mighty respect to have been named there". For Samuel Pepys, the King's business must come first, though he wished that he had been among those elected. Earlier in the month, he had set Creed down from his coach at Arundel House to attend a meeting of the Society, recording "whither I would be glad to go, but cannot".

March 5, 1668, was a great day for Samuel Pepys. For months criticism of the conduct of the recent Dutch War had been growing; and the national disgrace in the Medway



Gresham College, where the first meetings of the Royal Society were held.

The Great Fire of London, 1666. A view of Ludgate Hill and St. Paul's, with the tower of St. Mary-le-Bow in the background. ("*Picture Post*" *copyright.*)

rankled in the public mind; in the Commons there was a demand for the removal of the chief officers of the Navy. The defence fell to Pepys and he prepared it with his customary diligence. On March 5 he appeared at the Bar of the House and, in a speech that lasted three hours, he demolished the critics and the House passed to other matters. A week later he entered in his diary for March 12 an account of his attendance at a meeting of the Royal Society: ". . . I to Gresham College, there to shew myself; and was there greeted by Dr. Wilkins, Whistler, and others, as the patron of the Navy Office, and one that got great fame by my late speech in the Parliament. Here I saw a great trial of the goodness of a burning glass, made of a new figure, not spherical (by one Smithys, I think, they call him), that did burn a glove of my Lord Brouncker's from the heat of a very little fire, which a burning glass of the old form, or much bigger, could not do, which was mighty pretty. Here I heard Sir Robert Southwell give an account of some things committed to him by the Society at his going to Portugall, which he did deliver in a mighty handsome manner." Southwell had taken an astronomical quadrant to Lisbon, where some Portuguese mathematicians had undertaken to make observations.

After the meeting of April 2, 1668, he wrote: "Thence with Lord Brouncker to the Royall Society, where they were just done; but there I was forced to subscribe to the building of a College, and did give £40; and several others did subscribe, some greater and some less sums; but several I saw hang off: and I doubt it will spoil the Society, for it breeds faction and ill-will, and becomes burdensome to some that cannot, or would not, do it. Here, to my great content, I did try the use of the Otacousticon, which was only a great glass bottle, broke at the bottom putting the neck to my eare, and there I did plainly hear the dashing of the oares of the boats in the Thames to Arundell gallery window, which, without it, I could not in the least do, and may, I believe, be improved to a great height, which I am mighty glad of. Thence with Lord Brouncker and several of them to the King's Head Taverne by Chancery Lane, and there did drink and eat and talk, and, above the rest, I did hear of Mr. Hooke and my Lord an account of the reason of concords and discords in musique, which they say is from the equality of vibrations; but I am not satisfied in it, but will at my leisure think of it more, and see how far that do go to explain it." Music was one of Pepys's deep interests; and he must have enjoyed that evening. Hooke's ear-trumpet, the Otacousticon, met with the Society's approval and it was ordered that a larger one be prepared for the next meeting.

On June 22, at a Council held at Lord Brouncker's house, Pepys heard of proposals about the building of a college, but "my business was to meet Mr. Boyle, which I did, and discoursed about my eyes; and he did give me the best advice he could. . . ." Pepys's eyes were now giving him great anxiety and he was soon to abandon the diary which he had often written long after midnight. There remain only three further entries about the Royal Society. On July 16, he "saw an experiment of a dog's being tied through the back, about the spinal artery, and thereby being made void of all motion; and the artery being loosened again, the dog recovers"; on October 22, he heard "much good discourse"; and on November 30, 1668: "Thence by water, Mr. Povey, Creed, and I, to Arundell House, and there I did see them choosing their Council, it being St. Andrew's-day; and I had his Cross set on my hat, as the rest had, and cost me 2*s*., . . ." The custom of wearing a St. Andrew's cross on the anniversary meeting of the Society did not last, however, for many years.

The fear of blindness had now come upon him and he made his last entry in the diary on May 31, 1669: "And thus ends all that I doubt I shall ever be able to do with my own eyes in the keeping of my Journal, I being not able to do it any longer, having done now so long as to undo my eyes almost every time that I take a pen in my hand; and, therefore, whatever comes of it, I must forbear: . . . And so I betake myself to that course, which is almost as much as to see myself go into my grave; for which, and all the discomforts that will accompany my being blind, the good God prepare me!"

But ahead of Pepys there was still high office in the State, together with thirty-four years of membership of the Royal Society of which he would one day be President.

(*This article will be continued in the next issue of* DISCOVERY—EDITOR.)

Energy in the Future*

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In the second part of this article we are concerned mainly with those sources which may eventually supply a considerable part of the world's power, but the less important ones are also worth mentioning.

Wind and Waves

About 2% of the sun's energy falling on the earth is converted into energy in the form of wind, which thus represents a considerable source of power—but this is difficult to harness. Wind is not a very 'concentrated' source of energy and big structures are necessary to get even a smallish output. It varies very much in direction and intensity, it may on occasions be so violent that very strong structures are needed to withstand it, while on the average it is so light that the output of the plant becomes negligible. Then again, only a few favourable sites are available.

Wind will therefore not be able to contribute much to our power supplies. It may perhaps come in useful to drive smallish units at a few favourable locations, particularly if these could be coupled with the electricity grid so that the variation of output did not have too serious an effect.

At present, plants giving between 100 and 1000 kilowatts are under construction in various countries and may be of use in lonely places like isolated islands (see E. W. Golding's "Electricity from the Wind", DISCOVERY, March 1950).

Some part of the energy of the wind is transformed into energy of waves on the ocean and lately there has been considerable propaganda for utilising this energy. We have even been told that people looking for more power cannot see the wood for the trees: that there is a vast store of untapped energy before their eyes. It is quite true that the waves represent considerable amounts of energy, but I shall single out this example to show that not every store of energy, however obvious, is worth tapping.

One can calculate from the average height of the waves and their frequency that in order to build a power station producing 10,000 kilowatts, an area of about 10×2000 metres of sea outside the shore line would have to be covered with machinery. This alone shows that this source of power is not very concentrated, but there is another aspect. The size of a machine depends on the magnitude of the acting forces, while its output is equal to the product of these forces and the speed of the moving parts; this is the reason why modern machine design tends to faster and faster speeds. Machinery designed to utilise slow motion like that of the waves is bound to be clumsy and therefore inefficient. In addition we have to consider that the whole system has to stand up to storm conditions and that to provide against periods of calm we must store energy. This could perhaps best be done by pumping water up to a reservoir on a cliff; assuming a calm period of only two days, and the height of the cliff as say 30 metres, we would need a reservoir 6 metres deep covering an area of a square kilometre. If we consider that the same energy is stored in 200 tons of coal, and that a steam power station of this capacity covers only a few per cent of the area of the sea plant alone (without the reservoir), it is obvious that any saving of coal would be bought by much too great an effort. It is thus obvious that utilising the energy in the waves, although not impossible, has no future for large-scale power production and we would be in a sorry state if we had to depend on it. Similar considerations apply also to the next three power sources we are now going to discuss, as well as to the wind. This, of course, does not exclude the possibility that all these power sources may come in useful for small-scale power production in isolated places.

Heat of the Oceans

The energy represented by temperature differences in the ocean is very considerable, but the relatively small temperature differences and the consequent low thermodynamic efficiency of any plant working off them make it another source of very low concentration. There are few places in the world where a plant will be practicable, and even there the dimensions of plants giving even smallish outputs become very big indeed. The results of a gallant French experiment on the coast of West Africa are, however, awaited with interest.

The Earth's Heat

The heat contained in the interior of the earth represents a huge store of energy. The heat conductivity of rock and soil is very poor, and though this is fortunate for us in many ways it results in there being little possibility of making industrial use of the geo-thermic temperature gradient. There are a few places, however, in regions of volcanic activity, as for instance Italy and New Zealand, where very hot springs come to the surface of the earth. Italian engineers have done a good job in exploiting the hot springs of Tuscany and have thus made a very useful contribution to the power supplies of their country which is poor in ordinary energy sources.

Tidal Power

The total energy represented by the tidal movement of the oceans is not very impressive, and it is not in a concentrated form owing to the smallish differences in height and the slow turnover. In a few places where a tidal wave rushes up into an estuary, utilisation is technically possible. In particular a scheme in Great Britain, the so-called Severn Barrage Scheme, has been considered very carefully and it has been estimated that it could replace a million tons of coal burnt each year in a power station. The present cost of such a scheme would be about £100 million. When

* This article which is continued from p. 124 of the April issue is the essence of a report prepared by Prof. Simon for Unesco. The notes on nuclear energy and solar energy have, however, been extended and various small modifications made.

we consider that with half the capital investment 20 million tons of coal cculd be saved per year by improving heating appliances in Great Britain, it is obvious that such a scheme has no attractions. Tidal power stations on a large scale should only be considered if no other sources are available, and there is no sign of that.

Water-power

Water-power takes an intermediate position between sources of local and global importance. If all the water which we could utilise in a practical way were to be used in power stations it would supply about one-third of the world's present power consumption. So far about one-tenth of all the potential water supplies has been utilised; in North America and Europe about one-half the sources has already been tapped, but most of the considerable potentialities of South America and Africa remain unused.

Water-power is, of course, a very convenient form of power supply with relatively simple machinery although the building of the necessary dams is usually rather costly. It goes without saying that all potential water-power should be utilised to the full and certainly its development will be of major importance to Africa and other backward areas. It would, however, be futile to count on water-power for taking over completely from other fuels when they give out.

Nuclear Energy

We now go on to discuss those sources which may one day provide us with most of our power—the sun and nuclear energy.

Nuclear energy, or 'atomic energy' as it is misnamed, has unfortunately so much news value nowadays that a great deal of nonsense has been written about it. In general, scientists and engineers have not been responsible for this —although some astounding statements have appeared over the names of men who should have known better—but they cannot be absolved from the charge of not having contradicted the newspaper stories vigorously enough. Thus it has come about that the general public believes atomic energy to be just around the corner and that energy will soon be had for the asking. Yet even the development of the motor-car took some 30 years of slow and patient effort before it really made an impression on our way of life, and compared with the problems of nuclear energy the motor-car is a relatively simple device containing no fundamentally new ideas.

This loose talk has led to a reaction, so that many responsible people regard nuclear energy only as an unfortunate discovery with little or no value for the good of mankind. This is, however, going much too far. Nuclear energy will certainly have many important applications in specialised fields in the foreseeable future, and it is quite possible—or even probable—that towards the end of the century it may make a considerable contribution to the world's power needs.

The Nature of Nuclei

Atoms were once regarded as indivisible units, but we know now that they are built up from smaller particles and that they consist of a heavy nucleus electrically charged with a cloud of electrons surrounding it. Most of the physical and all the chemical properties of the atom, including in particular the chemical affinity, reside in the electronic cloud. When atoms combine to form chemical compounds a rearrangement of the electrons in these clouds takes place but the nuclei remain unchanged.

The nuclei also have been shown to consist of smaller particles—charged protons and uncharged neutrons. The fact that the nucleus is not affected by normal physical or chemical changes shows that the particles of which it is constructed are linked together by very strong forces. This implies that if we can rearrange the particles in them—i.e. carry out a nuclear 'chemical' reaction—there may be an evolution of energy on a very much greater scale than is associated with ordinary chemical changes.

How can we tell whether such a thing is possible? Einstein's relation between mass and energy shows that the answer can be found by weighing the atoms very accurately, and this is done in the so-called mass spectrometer. It turns out that the atoms with medium atomic weight are more stable than those with lower or higher weights. We can in principle gain energy if we combine light atoms to form somewhat heavier ones or if we split very heavy atoms into somewhat lighter ones.

It is one thing to know that a process is possible and another to find a way to carry it out in practice. Let us consider the prospect of producing energy by the first alternative of combining light atoms. Very considerable amounts of energy should be released when four hydrogen nuclei combine to form one helium nucleus, and we know that this 'thermo-nuclear' reaction is responsible for the production of energy in stars. A detailed analysis shows, however, that this reaction is an improbable event; so improbable that in a million million years it would not happen once spontaneously in the whole universe. The reaction can be 'coaxed' or catalysed by the so-called 'carbon cycle', and this very complicated process is going on in the interior of the stars. Even in the interior of the sun, however, where the temperature is some 20 million °C. the reaction takes many millions of years. There is a possibility that conditions favourable for this reaction can be created artificially for extremely short periods; this is the basis of the hydrogen bomb which is now very much in the news. So far, however, nobody can envisage how this reaction can be realised in a controlled way for power production. A year ago, it was claimed in the Argentine that they had succeeded in doing so, but I do not know of any serious scientist who attaches any weight to these claims. It should be emphasised, however, that *in principle* the problem can be solved and it is not out of the question that in the more distant future thermo-nuclear reactions will provide much, if not most, of our power, particularly as there will never be a shortage of the raw material, hydrogen.

The second possibility, that of splitting heavy atoms, was achieved during the war by the fission of uranium. Neutrons are very powerful weapons for attacking nuclei, as owing to their lack of electrical charge they are not repelled away. It was shown shortly before the war that the uranium nucleus can be split into two not quite equal parts by bombarding it with neutrons, and that during this reaction, energy is released on a scale about a million times

higher than that associated with the combustion of chemical fuel. If we have to produce these neutrons ourselves a lot of energy is required and no net energy gain results. It turns out, however, that a number of neutrons are released during the fission process and these are sufficient to start a chain reaction or, in other words, to make the reaction self-propagating. This presents us with the possibility of power from nuclear energy.

Nuclear Fission

Uranium consists chiefly of two isotopes, the so-called U235 and U238, the U238 being 140 times more abundant. Isotopes are atoms possessing the same nuclear charges and consequently the same sort of electron clouds, but having a different nuclear structure. Although nearly all their chemical and physical properties are very similar, they may behave quite differently from the nuclear point of view. The most important of these differences in our case is that U235 can be easily split by neutron bombardment, while U238 nuclei normally absorb neutrons without being split.

If the fission reaction has once started in a piece of normal uranium, the condition for it to keep going is that at least one neutron originating from the fission of each nucleus goes on to split another one. Now neutrons can be lost by absorption in 238 nuclei, by absorption in the various materials which must be used in the construction of the nuclear furnace or 'reactor', and finally by escaping altogether through its surface. In order to get enough neutrons to create a chain reaction to explode the bomb, nearly pure U235 had to be used and this was separated from the U238 in enormous diffusion plants in America.

The neutrons in the bomb produce further fissions very soon after the fission which produced them and when they are travelling very quickly. These fast neutrons give a runaway explosive reaction; for power production we require a controllable reaction, and one way to achieve this is to 'slow' neutrons which can be produced by slowing down the fast ones in a 'moderator'. Slow neutrons also have the useful characteristic that they are not so readily absorbed by U238, thus it is possible to use natural uranium consisting of both U235 and U238 for power production. This is done in a pile where blocks of uranium are interlaced in a certain way with a moderator consisting of, for instance, graphite or heavy water. Although heavy water is much better from the nuclear point of view, it is expensive to produce. In such reactors uranium 235 is consumed and the energy of the fissions is converted into heat, which has to be carried away by a cooling medium. The neutron bombardment of the U238 in the reactor leads to the formation of a new fissile material called plutonium which behaves similarly to U235.

Nuclear Reactors

It should be emphasised that nuclear energy is free energy, but we have seen that when it is released in a reactor it is converted only into heat energy. It seems to be much more difficult to think of a way to transform it directly into, say, electrical energy than is the case with chemical energy. In order not to lose too much we must run the reactors at temperatures at least comparable to those used in modern steam power plants, i.e. 500°C. The materials of which it is made must stand up both to these temperatures and to the extremely powerful radiation, which is strong enough to knock uranium nuclei to pieces. As very few elements can be used in it from the nuclear point of view—they must not absorb neutrons to any extent—very difficult problems have to be solved. In order to transport the heat energy from the reactor to a conventional type of steam power plant, some cooling fluid will have to circulate between the two. This fluid and the tubes it flows through will almost certainly be contaminated with highly radioactive material, and if repairs are needed it will be necessary to wait for many months until the defective part can be approached. It will, of course, be even more difficult to make repairs and adjustments to the constituents of the reactor itself.

There are various types of reactors. The ones employed so far for the production of plutonium mostly use ordinary uranium together with graphite as a moderator and are very big. If heavy water is used as a moderator the size becomes very much smaller, but, of course, heavy water is expensive. The size can be further decreased by working with enriched fissile material, either separated 238 or plutonium, but they are difficult to produce and in addition have military applications. To protect the operators, all piles have to be surrounded by shields which are generally of concrete many feet thick; hence, all ideas of nuclear motor-cars or even locomotives must be written off.

It is a popular misconception that the only important part of a nuclear power plant is the reactor. One of the most critical items, however, is a chemical separation plant which is needed to separate the plutonium and other fission products formed in the reactor from each other and from the ordinary uranium. These separation plants are very big and, of course, they can only be operated by remote control, so that they are responsible for a large part of the total cost.

A further member of the very complex unit needed for the large-scale production of nuclear power is an isotope separation plant. Such plants are essential not only for producing enriched fissile material but also to re-enrich uranium partially depleted in the reactor; again these plants are very large in size, and costly. Isotopes of the heavy elements in particular are so near each other in all physical and chemical properties that a very great number of stages, connected up in a complicated way, is needed to achieve any material change of concentration; in a diffusion plant, for instance, the substance has to pass through thousands of stages which consist of molecular 'sieves' and the published photographs of the American diffusion plant (see DISCOVERY, September 1945, p. 261) show the enormous size of these installations.

Supplies and Economics

Before entering into a discussion how nuclear power can be used we have to say something about the all-important supply question. The starting-point for every scheme is uranium, while thorium can be used as an auxiliary fuel. These substances are not exactly rare, but there are few really concentrated deposits and if we had to rely on these, atomic energy could not provide any noticeable fraction of

our total power supplies for any prolonged period. There are, however, two possibilities which may change matters radically: (*a*) There exist very widespread deposits of uranium ore of low and very low grade. If methods can be found to separate off the uranium in a fairly economical way, the available store of fissile material would be quite dramatically increased.

(*b*) The other possibility is to use up the uranium 238, which is so much more abundant than the 235. A possible way of doing this exists in the so-called 'breeding' process, in which more than one new fissile nucleus is built up in a reactor for each 235 nucleus which disappears. It is not yet quite certain whether this process will work, but what is certain is that to breed a useful stock from the existing material would take several decades.

Every large-scale, peace-time energy scheme must, of course, have a sound economic basis. A lot of irresponsible data has been published, particularly on the other side of the Atlantic, giving the probable cost of atomic energy to within a few per cent. After what I have said about the complex structure of the whole power-producing system and the fact that so far no power pile has yet been run, it is obvious that it is quite impossible to give any estimate except in the vaguest terms. May I mention as an example a discussion which took place recently in America about producing petrol by coal hydrogenation. All the details of this process are well understood and large-scale pilot plants have run for a long time. Nevertheless, the estimates of the price at which it will be possible to market the petrol differ by a factor 3! How much bigger must be the uncertainties in our case?

At the present stage of development it would be quite unreasonable to ask for any exact data. It is sufficient to state that eventually nuclear power may cost no more than power produced by coal. This is quite sufficient to warrant further development.

One other point has to be mentioned which is of importance for this country and which is often overlooked. If a large part of our power should ever be derived from uranium we must bear in mind that this raw material has to be imported. That means that we would have to increase our exports to pay for the uranium. On the other hand coal is available in this country. The fact that it is in short supply is not due to depletion of our stocks but because we have not solved the human problems in the mines. By the time nuclear power becomes a reality this situation might well have changed.

Prospects for Nuclear Energy

Let us assume now that all the technical problems have been solved—and it is certain that they can be solved—what will be the chief applications of atomic energy? Its main advantage, of course, is in the negligible weight of the fuel, so that it would seem predestined to drive vehicles. On the other hand we have seen that the minimum size of a reactor is such that it is completely excluded for smaller vehicles. A very promising field would, however, be the propulsion of big ships. Also it might become possible to build biggish power plants in inaccessible areas, to provide power for the irrigation of deserts and similar projects. Though all this is quite interesting and not without importance, the really large-scale application of nuclear energy depends on the cost and availability of raw materials.

It is hard to say how much energy can be derived from the uranium and thorium which is readily accessible, particularly as much of the necessary information has not been made public. A rough estimate, however, shows that even with breeding it cannot be much more than the energy stored in our present fuel resources. Even this restricted amount, however, would be a welcome addition to our chemical fuels, particularly for those countries which have no large-scale deposits of conventional fuels.

It is difficult to predict when nuclear power can begin to share the load with coal. So far no prototype of a big power-producing reactor has yet been running, and it probably will be a number of years before this takes place, at least in this country. Until this happens we will not be able to gain any real experience which only comes from running an actual plant under realistic conditions for a number of years. Only after this had been done will it be possible to design the next series of prototypes; then these will have to be run until one can expect the authorities to stake their money on really large-scale plants. Let us consider as an example the building of power stations corresponding to 50% of the present power output of our electricity stations, i.e. to replace 8% of the total coal consumption of this country. This would necessitate a capital investment of about £1000 million, and no one would invest such a sum without being one hundred per cent sure that all the technical problems have been solved, as well as that the fuel supplies for a long time to come are ensured.

The time scale will, of course, depend on the priority which the project is given. This priority has not been very high anywhere in the world as the emphasis has been more on the military side. Another reason for the relatively slow start-up is that the smallest unit which we can experiment with costs a few million pounds. Also this country is very short of the right sort of technologists, particularly chemical engineers and metallurgists who, contrary to common belief, are at this stage the real 'atom men'—not the physicists. Considering all the factors, my guess is that it cannot take less than 30 years to generate half our present electricity production from atomic fuel. In actual fact, considering what has happened in the very much simpler case of the stationary gas turbine, I would think this a very optimistic estimate. On the other hand in 30 years' time our electricity production must have expanded at least by a factor of 3 if this country is going to keep—or better regain—its position as a first-class industrial power, and compared with this expansion the additional energy discussed in our example is very small. Thus it would seem that atomic energy will not be able to shoulder a major part of the electricity load before the end of the century.

To sum up the prospects for nuclear energy: it certainly has applications for some specialised processes, which, though very promising, are not of overriding importance, and we may expect a few power reactors to be running in the next decade, although not yet as an economical proposition. We can also foresee that nuclear energy may become a useful and even a decisive factor in the economy of regions without other energy sources. Whether there is enough fissile material available to provide a considerable part of the world's power supplies remains to be seen. Even

if the question is answered in the affirmative, it will take at least several decades until nuclear energy can make a definite impression on the world power situation. In any case our supply of nuclear energy will not last longer than our stocks of chemical fuels, until thermo-nuclear reactions can be effected in controlled processes. They form the real hope for the more distant future.

Solar Energy

There is one nuclear reactor which is enormously powerful at a safe distance, and free for all: the sun! Of course, everyone knows that all our food is grown by energy derived from the sun, that our fuels are remains of former plant life which got its energy from the sun, that the wind's energy originates in the sun's radiation, and so on. But hardly any attempts have been made to harness the sun's energy *directly*.

Let us first consider orders of magnitude. The power radiated from the sun is about 1 kilowatt per square metre measured just outside the earth's atmosphere. The intensity at the surface of the earth is less than this, as some of the energy is partly reflected and partly absorbed by the atmosphere, and we have to consider the variation due to the changing angle of incidence. Taking all these factors into account and assuming that 10% of the energy can be utilised, we find that a total area of the size of Egypt (without the Sudan) would be sufficient to supply the power requirements of the world at the present moment. There are thus great latent possibilities, but it is also clear that we will have to cover very extensive areas with receivers for the sun's energy. Therefore the receiving mechanism must be cheap and simple.

The energy of solar radiation corresponds to a very high temperature; it is therefore mainly free energy, *not* heat. The proper way of tapping it is not to use it as heat, but to find a process which will convert it directly into another form of free energy more useful to us. Here again, the living cell has got further than the scientist, just as our bodies have done in turning the free energy in our food into mechanical energy.

The few attempts to obtain solar energy made so far have used the radiation only to produce heat at a high temperature to operate small thermal prime movers. The units up to now have been very small, and it is doubtful whether we will ever get an appreciable amount of power in this way. The mirrors needed to concentrate the radiation are much too costly, particularly as they must incorporate a device to keep them pointing towards the sun. Another way of using the radiation as heat energy would be to utilise thermo-couples which convert heat directly into electrical energy. The efficiency is, however, very low, and general considerations suggest that we will never be able to increase it very much. Nevertheless, it is a line of approach which might have some application for small units.

Attempts have also been made to use the energy of radiation directly to heat houses. Installations of this kind are quite practicable and may be useful, but only in a few favourable locations; one might also design small, cheap stoves for countries like India which are so short of fuel that they often burn cows' dung which is badly needed for fertilising their fields. These applications, however, can never make any appreciable contribution to the vast quantity of power that the world needs.

How then can we make use of the free energy of solar radiation *directly*? One obvious scheme is by way of plants (including trees). By the catalytic action of their chlorophyll they can use sunlight to synthesise water and carbon dioxide into carbohydrates of higher free energy. In order to use this free energy for power production, it seems that at present we have still to fall back on the easy but wasteful way of converting it into heat to operate thermal prime movers. This can be done either by burning the vegetable matter under the boilers of steam engines or by fermenting it and producing alcohol for internal combustion engines. It should also be possible to convert vegetable matter directly into fuels of the petrol type. It is true that in this case we would again be converting the energy into heat, but the heat energy of fuels can be utilised at much higher temperatures than are likely to be obtained by heating boilers directly with sunlight. The trouble is that the efficiency of the conversion of the energy of sunlight into chemical energy by means of the ordinary crops is very low; generally it does not even reach 1%. There is at present no obvious way to increase this efficiency, though very little research has been done so far. Nevertheless, in some countries not provided with other power sources the burning of timber is used on a large scale; for example in Finland more than half the locomotives run on wood. It has been calculated that a eucalyptus forest about 30 square kilometres in area could keep a 10,000-kilowatt power plant in continuous operation. This again is, of course, a very big area but it is not covered with machinery, only with trees, and there may be places in the world where for a limited period this might not be an impracticable suggestion.

Another way, perhaps more promising, would be to use either freshwater or marine plants to promote photosynthesis on an industrial scale. In particular, algae seem to be prolific producers of vegetable matter, especially if high concentrations of carbon dioxide are present. They might be grown in big troughs through which a slow stream of water flows and delivers a harvest of algae at one end of the 'conveyor belt'.

An important problem involved in the industrialisation of photosynthesis is that locations favourable from the radiation point of view are very often those of great water shortage. Plants evaporate a great amount of water which is then lost so we would have to pump very large amounts of water to the system, which would restrict it to a very few locations and make it most uneconomical. In this age of cheap plastics it might be possible to cover large tracts of land with glass or plastic roofs so that the water would not be lost but would, so to speak, circulate in a closed cycle. These roofs would also enable us to increase the carbon-dioxide concentration above the troughs by feeding back the carbon dioxide produced when the algae are finally burnt or fermented. In this way the same water and carbon dioxide could be made to serve our purpose over and over again, and in addition we would have the advantage of being able to set the concentration of the carbon dioxide at the most favourable level. Many problems remain to be solved but there is no reason why we should not start now to experiment on a largish scale particularly as we have obligations towards the underdeveloped areas.

In principle it should also be possible to be quite independent of plants, and to use the sun's radiation in a chemical reaction producing a compound with a large free energy, or even to convert the radiation directly into electrical energy by an electrolytic cell. Such a direct conversion of solar radiation into electrical energy is also possible by the use of photocells, as now used in exposure-meters for cameras and in many regulating devices. So far, the efficiency of these instruments, taken over the whole spectrum of sunlight, is not very high, but progress is being made continually. It seems quite possible that future solar energy installations might be built.

Conclusions

This survey of the relevant facts has, of course, been a very summary one. For example, we have not mentioned the problems of energy storage and of the long-range electrical transmission of power. We should also have emphasised that food production is often competing with energy production for space under the sun. This is obviously true when we attempt to use solar energy, but is also relevant to our use of water supplies. However, these points do not change the overall picture.

What will happen in the distant future, when we can no longer count on considerable stores of chemical fuel and fissile material? Perhaps we shall derive our power directly from the sun and from thermo-nuclear reactions. It is likely that we shall produce the energy in a relatively small number of big power stations and distribute it over very long distances in the form of electricity, perhaps making use of direct-current, high-voltage transmission. For light transport—cars, ships, and aeroplanes—accumulators of very much lighter weight than at present may perhaps become available. It is more probable, however, that we will have to depend on fuels of the kind we are using now. After the exhaustion of the stores of these fuels laid down in former ages, we shall still be able to synthesise them from existing raw materials (e.g. air, water and carbon dioxide), provided power is available.

The picture for the near future is not so clear. There are as yet no new power sources available which can help us during the next few decades. The power sources which we will have to use are very unevenly distributed, and it will probably become increasingly difficult to get people to go down the mines. On the other hand, it is obvious that our power consumption will increase. What then must we do?

The first thing is to make better use of our present supplies, and we have seen that this should be easily possible. We must economise in our use of power, but it should be emphasised that this does not imply that we have to go short of something; actually we will be better off in many ways. To realise this, let us ask whether we should go on throwing power away as we do now even if fuels were available in unlimited amounts. The answer is definitely 'No'. First it is unjustifiable to force people to do more of such unpleasant work as mining than is absolutely necessary. Then to erect power stations and build distribution systems in order to waste the greater part of the power means that we are depriving ourselves of labour and material which could be used to enrich our lives. For instance, we are still throwing away all the low-temperature heat from our power stations which could be used for space heating. Unfortunately our electricity undertakings have not yet really grasped the fact that they are producers of two forms of energy both of which have their value: electrical energy and much greater amounts of low-grade heat. Indeed, at present they regard this heat as a disreputable 'corpse' to be disposed of as inconspicuously as possible. The effect is that it is allowed to run to complete waste while miners are having to win coal which will only be burnt to provide just this kind of low-grade heat.

There are other reasons why we should not go on wasting power as we do now. The waste does not just vanish. Sometimes it appears in the form of smoke and soot which soil our towns and houses, sometimes as heat which is generally very difficult to get rid of. Indeed the disposal of heat produced in inefficient processes is often the limiting factor in the design of machinery. In big plants the heat is taken away by transferring it to water, generally from a river or pumped from underground wells. For each ton of coal burned even in the most modern power station about 500 tons of cooling water are needed. For every ton of coal used in steel-making 250 tons of water are required, while the figures for chemical industries are higher by a considerable factor. It is clear that enormous amounts of cooling water are necessary to carry away the decayed remains of the wasted free energy. The demands on water by industry are so big that in many places the level of the water in the ground is falling at an alarming rate. Industry has now often to choose its sites, not where power, fuel or basic materials are to hand, as it naturally would, but where water is available. Thus our wasteful methods force us into yet more unnecessary efforts.

What we have to do then is first to increase the efficiency of our machines and heating appliances; secondly, to develop all our present power resources, in particular water power, to the economic limit; thirdly, to start long-range developments now of new power sources.

As a beginning to this threefold programme, research and development on a vast scale are needed. At present only nuclear energy gets proper attention (though nobody pretends that this is due to the peaceful benefits that it can bestow upon us). While one would not advocate cutting expenditure in this field which shows so much promise in various directions, comparable sums should be spent on other projects such as solar energy, the fuel cell, underground gasification of coal—to name only a few. Even if we were to spend as much on these as we do on nuclear research, it would be small in comparison with the return they are bound to yield.

There are some people, however, who advocate stopping all research because they think that science is responsible for all our present troubles and more often than not they single out nuclear energy as a particular offender. In my opinion these views are quite mistaken. First of all, such a suggestion could only be considered if everybody in the whole world would fall into line; this seems only possible if some world-wide organisation could enforce the standstill order, but if such an organisation existed there would be little need for the moratorium. Secondly, there is no reason why the argument should be particularly applied to atomic energy; should we for instance abandon biological and medical research because of possible military applications?

ECLIPSE 1952

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On February 25, 1952, a partial eclipse of the sun was visible in Britain. Londoners in particular had a good view as slight fog cut down the sun's glare and so made it possible to observe the progress of the eclipse with the naked eye. At the Royal Greenwich Observatory in Sussex, however, nothing could be seen.

In other parts of the world a total solar eclipse occurred; the path of the eclipse is indicated on the map printed above. In Khartoum, over sixty scientists belonging to seventeen separate expeditions observed the total eclipse. According to 'The Times' correspondent who was with them, most of the astronomers were engaged in direct optical observation; some took photographs of the chromosphere and of the corona, and others measured the intensity of light given off by the corona. A United States naval research expedition concentrated on radio astronomy, and an expedition from the Astrophysical Institute in Paris undertook similar work. The National Geographic Society of America used a powerful telescopic camera. University College, Khartoum, carried out ionospheric research.

Dr. John Bloss, who took our photographs of the astronomers' activities at Khartoum, saw the eclipse from the parapet of a military fort. He writes, "Below me were the Dutch expedition, then the British team from Cambridge University under Professor Redman, the Irish team from Dunsirk Observatory, and the French party from the Astrophysics Observatory of Paris. In other parts of Khartoum were the U.S. Naval and Air Force research teams, the Swiss, the Egyptians and the Italians. British soldiers of the R.E.M.E. were helping some of the parties. Professor Redman had a spectrograph some fifteen feet underground, and the smallest soldier they could find was down there helping to manipulate it."

The scientific preparations for this eclipse began over two years ago. As every moment of the 189 seconds of eclipse was valuable beyond words, every precaution was taken to ensure that the instruments would work without a hitch. Some of the apparatus was set up two months in advance, and for days beforehand the scientists rehearsed their prodecure.

There will not be another total eclipse until 1970.

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FIG. 2.—A radio telescope which measures the 10-cm. rays. emanating from the sun, coming from the infra-red end of the spectrum. It is operated by Mr. Haddock of the U.S. Naval Research Laboratory, Washington, encamped at Khartoum.

FIG. 3.—A special triple spectrograph for studying the atmospheric layers directly outside the sun, the chromosphere. This apparatus comes from the High Altitude Observatory, Boulden, Colorado.

FIG. 4.—Two cine-cameras used by the U.S. Naval Research Laboratory team for taking movies of the eclipse with 80-cm. and 40-cm. lenses, one in colour and one in black and white.

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FIG. 5.—Leading Army and Air Force personnel watched the eclipse from the parapet of Fort Stanley, at Khartoum. Among the officers are Colonel Elstone, O.C. the South Lancs., and Group Captain Coates, O.C. R.A.F.

FIG. 7.—Observers watch progress towards totality, while last-minute adjustments are made to a spectrograph. This photo shows members of the Cambridge University party which was led by Prof. Redman.

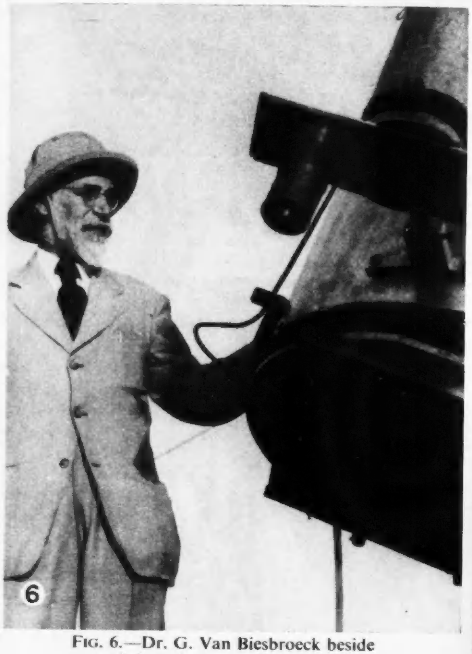
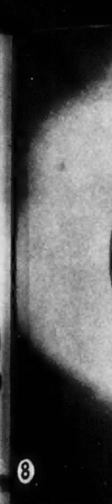


FIG. 6.—Dr. G. Van Biesbroeck beside one of the telescopes of the National Geographic Society. Note size of plate used to record eclipse.



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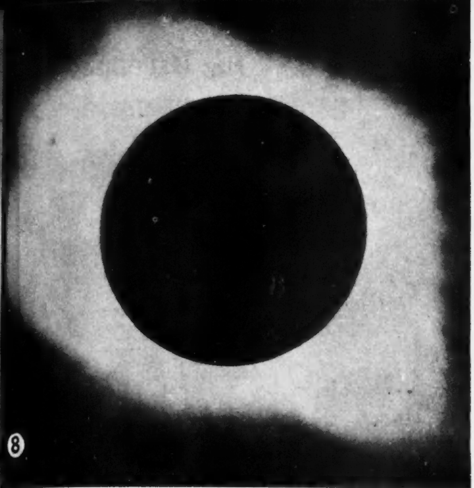


FIG. 8.—Total eclipse of the sun at 11.9 Sudanese time (two hours in advance of G.M.T.). The sun's rays illuminate the darkened sky around it. (Photo by David S. Hawkins and Dr. John P. Hagen of U.S. Naval Research Laboratory, Washington.)

FIG. 9.—This eclipse picture was taken at the U.S. National Geographic Society's camp at Khartoum. On the right is the giant camera this expedition used to photograph the event.

FIG. 10.—The Sudanese people were told in advance about the eclipse over the radio and by word of mouth; nevertheless, many were terrified by the phenomenon and locked themselves in their houses. Bolder spirits stayed by the scientists' camps on the Khartoum road and viewed the eclipse through pieces of exposed photographic film.

FIG. 11.—A view of the U.S. National Geographic Society's camp with its giant camera on right of wigwam-like tent. The photograph was taken as the eclipse moved towards its climax.

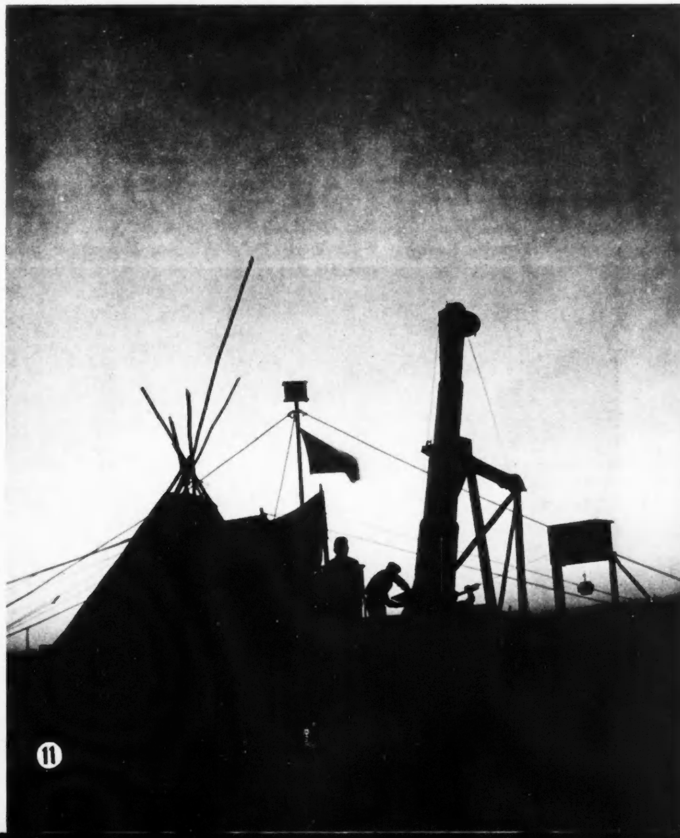


FIG. 1.—Rose-bay Willow-herb (*Epilobium angustifolium*).

FIG. 2.—Willow-herb spreads like wildfire because of the very efficient wind-dispersal of the tufted seeds, here seen escaping from the seed capsule.

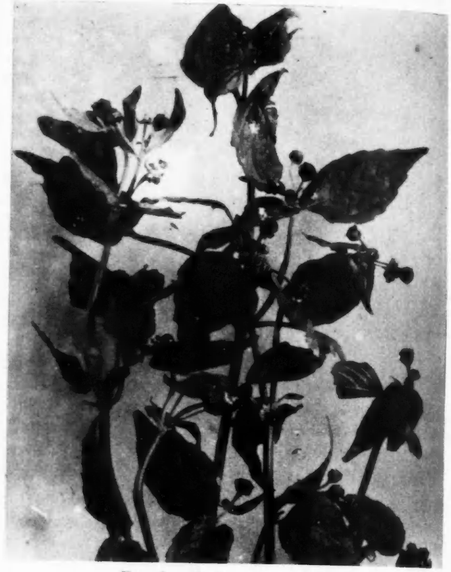


FIG. 3.—*Galinsoga parviflora*.

FIG. 4.—*Veronica buxbaumii*.

Weeds to the gardener with sore fingers and a sore back are plants that grow where they are not wanted; as one shrewd gardener put it, "They don't realise that they have an allotted place in a particular bed, and that they must stick to it." But it is a shade pompous to think of 'orderly' and 'disorderly' plants. Flowering plants have been on the earth for at least as long as human beings, and it would be to lapse into anthropomorphic error for us to libel those plants which show no respect for mapmakers' frontiers by applying to them the word 'weed' in its abusive sense. If a weed is defined as a plant growing outside its own territory then it is no more and no less of a foreigner than any cultivated plant you care to think of, for there is foreign stock in most, if not all, commercial crop plants grown by farmers and gardeners. Weeds are just migrant plants with a capacity for rapid reproduction, and they tend to swamp our cultivated plants because they are healthier and more vigorous, being better suited to the environment. This article deals with some of the weeds which have wandered about the British countryside, adding to the picturesqueness of the landscape and spreading backache wherever they go.

Plants Beyond Control

HAROLD BASTIN

A weed, as defined long ago by a disgruntled gardener, is 'any plant growing in the wrong place'—the wrong place, of course, being the spot where it is unwanted by the individual registering the complaint. But Dame Nature is no respecter of persons. She sows her seeds broadcast, alike on waste and cultivated land; and when they fall on congenial soil they germinate and—if left alone—flourish whether men want them or not. Hence the problem of weed eradication is a perennial one, incapable of final solution by any conceivable means short of exterminating plant life altogether on the globe—which, from the standpoint of mankind and his animal associates, would obviously spell suicide in the most literal sense.

Nevertheless, much can be, and in fact is being, done towards the suppression of weeds in particular areas, and as far as possible to correct errors and miscalculations which in the past have actually assisted the spread of noxious vegetation from one country to another—as, for example, the introduction (apparently from merely sentimental motives) of the sweet-briar and the thistle into Australia and New Zealand, where they soon became veritable plagues. The Prickly Pear, a cactus which is nature's equivalent of a barbed-wire fence, is perhaps a more serious weed in that it has reduced to wilderness large areas that might otherwise carry sheep; it is, however, a relatively easy weed to eradicate. The Bathurst and Noogoora burs, stinging nettle, shepherd's purse and several docks are now almost cosmopolitan in their range, having been carried about with wool and other commodities, or with imperfectly cleaned consignments of agricultural seeds. Nearly all the most aggressive weeds in North America today—daisy, dandelion, burdock, buttercups, thistles and a host of others—are of European origin, while a similar though less numerous transit has occurred from west to east across the Atlantic.

Plants which we have good reason to believe have formed part of our flora since glacial times are classed as indigenous or 'natives'. The rest, known or suspected to have been introduced by one means or another during a later period, are termed 'aliens'; and these again may be arranged roughly in three groups, which we may call 'denizens', 'colonists', and 'casuals'.

Denizens are immigrants which have so successfully established themselves among the natives that they now form a definite part of our British flora. A classic example is the Canadian water-weed (*Elodea canadensis*), which was unknown on this side of the Atlantic until it made its appearance in Ireland in 1836 and in England some five years later, but is now one of the commonest aquatics throughout the British Isles. For a time scientists jokingly called this weed *Babingtonia abominabilis*, so honouring the great systematist. River and canal navigation is apt to be impeded by its presence, while it seriously interferes with angling in lakes and slow-moving streams. It does, however, make an excellent aerator for aquaria, and it has been a favourite with plant physiologists studying photosynthesis. An interesting feature of its dispersal is that our British plants appear to constitute what botanists call a 'clone': i.e. they are all the vegetatively produced progeny of the original contingent—this because the male and female flowers of the species are borne by different individuals, and those so far found in Britain have been almost exclusively male plants.

Much less rapid has been the spread of the handsome rose-bay willow-herb (*Epilobium angustifolium*), also known as Canadian fire-weed, which invaded London on a grand scale after the blitz and now flourishes on many a ruined site. Gerard, in the sixteenth century, wrote of it as a rarity, having seen it growing wild in one locality only; while even in the mid-nineteenth century it was described in the first edition of the Rev. C. A. John's popular but trustworthy handbook (*Flowers of the Field*) as "rare in a wild state . . . but very common in gardens". In short, it may well have often been a garden 'escape' which nowadays is found commonly in localities that suit it all over the Northern Hemisphere. It likes open spaces, and—as the popular name 'fire-weed' suggests—is partial to recently burnt soil, which most plants abominate; but in view of its prodigious production of airborne seeds the relative slowness of its dispersal is hard to explain. Though it is hard to eradicate once it is firmly established as has happened in some of the southern counties of England, particularly in places where woods have been ruthlessly destroyed without regard to the needs of the future.

Few denizens can be regarded as weeds in the strict sense of the word; but an exception must be made of two species of *Claytonia* (*C. alsinoides* and *C. perfoliata*)—annuals from North America which are not confined to

heaths and roadsides, but in many parts of Great Britain spring up abundantly on cultivated land. Also, several American wood-sorrels (e.g. *Oxalis corniculata* and *O. stricta*) which long ago made themselves a permanent home in England, have invaded our gardens and allotments to a disconcerting extent.

Among many other aliens which have established themselves with us as denizens, the following may be mentioned, together with their places of origin and the approximate dates of their first recorded appearance:

Evening Primrose (*Oenothera biennis*), North America, 1534.
Roman Nettle (*Urtica pilulifera*), Mediterranean region, 1640.
Viscid Groundsel (*Senecio viscosus*), Central Europe, 1660.
Winter Heliotrope (*Petasites fragrans*), South-eastern Europe, 1770.
Oxford Ragwort (*Senecio squalidus*), Mediterranean Region, 1794.
Tawny Balsam (*Impatiens fulva*), North America, 1822.
Monkey Musk (*Mimulus guttatus*), California, 1830.
Small-flowered Balsam (*Impatiens parviflora*), Russia, 1838.

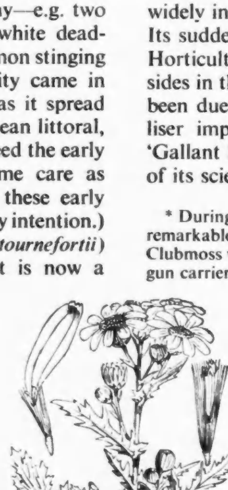
The common balsam or touch-me-not (*I. noli-me-tangere*), from Siberia, seems to have grown "in rocky and shady British woods, chiefly in the north" time out of mind; while according to Brimble, the pink balsam (*I. glandulifera*)—a native of Ceylon, and until recently regarded by florists as a greenhouse annual—has during the past few years established itself, sometimes in abundance, along several of our southern river banks.

Most of the common weeds of cultivation are colonists: that is, they have gained a permanent footing on arable and waste land and in gardens, but have not been able to compete with the native vegetation, and so do not figure in any of the regular 'communities'. But many—e.g. two of the procumbent speedwells, the red and white dead-nettles, field brome grass and possibly the common stinging nettle—are old-stagers which in all probability came in the track of primitive agriculture from Asia as it spread gradually westward, first along the Mediterranean littoral, and then northward through Europe. (The seed the early farmers used was not selected with the same care as reputable seed firms exercise today, so that these early 'foreign invaders' came more by accident than by intention.) Others, such as Buxbaum's speedwell (*Veronica tournefortii*) are comparatively recent arrivals; this plant is now a common field and garden weed in all parts of the British Islands, but it was not recorded before 1825.

The so-called casuals are aliens whose eventual status is still undetermined. They have, perhaps, been brought with merchandise from other lands, or they may be the descendants of garden throw-outs or 'escapes'. The majority soon perish, either from failure to produce fertile seed, or because in a novel terrain they cannot hold their own in the struggle for existence. But a few—after a longer or shorter period of probation—succeed; and it is from among these fortunate ones that our 'weeds of tomorrow' are recruited. A typical example is the rayless chamomile (*Matricaria suaveolens*) from western North America. Its popular name of 'pineapple-weed' refers to the fragrance which it exhales, especially when crushed; and as one writer has said, "the more it is trodden on the better it seems to thrive". First recorded about 1870, it made little progress up to the beginning of the present century, but since then has become common in almost all parts of Great Britain south of the border, as well as in Ireland. Commenting on this, Sir Edward Salisbury—our leading authority in these matters—suggests that this rapid extension subsequent to 1900 was probably due to the coincident increase in motor transport, and points out that "the patterned tread of the motor tyre is a peculiarly effective means of dispersal of mud containing seeds, which may be conveyed long distances before shrinkage on drying results in its dislodgment from the depressions of the pattern".*

Our most recently acquired weed is an interesting composite, with a five-rayed inflorescence whose disc-florets are said to be the smallest individual flowers in the world, having a length of only 1 mm. and a diameter of 0·3 mm. Introduced from Peru into the Royal Botanic Gardens at Kew in 1796, it was first recorded as an escape in 1863, when it was found to have naturalised itself over an area between Kew and East Sheen. It is now dispersed fairly widely in the south-eastern counties, and is still spreading. Its sudden appearance during the war years in the Royal Horticultural Society's orchards at Wisley and along roadsides in their immediate neighbourhood is believed to have been due to a fresh introduction of seed in tankage fertiliser imported from Argentina. Its colloquial name of 'Gallant Soldiers' is a rather defective phonetic rendering of its scientific generic title which is *Galinsoga*.

* During the recent war, tanks appear to have caused some remarkable transfers of plant species; for instance, a species of Clubmoss would appear to have been introduced by tanks or Bren-gun carriers into one southern vice-county from Scotland.—*Editor.*



Oxford Ragwort (*Senecio squalidus*). A Mediterranean plant introduced to Britain about 1794.

Far and Near

New F.R.S.s

The following is the list of new Fellows of the Royal Society, whose election was announced on March 20, 1952:

Akers, Sir Wallace Alan, C.B.E. Director, Imperial Chemical Industries Ltd. Distinguished for his technical direction of the atomic energy project during the war and for the building of large research departments and plants in Imperial Chemical Industries.

Bawn, Cecil Edward Henry. Grant-Brunner Professor of Inorganic and Physical Chemistry, Liverpool University. Distinguished for his researches on chemical kinetics, especially on the mechanism of polymerisation, oxidation and hydrocarbon-free radical reactions.

Berrill, Norman John. Strathcona Professor of Zoology, McGill University, Montreal. Distinguished for his analytical studies of development, morphogenesis and regeneration, particularly in the Tunicata on which his monograph, published by the Ray Society, is now the standard British work.

Craigie, John Hubert. Associate Director, Science Service, Dominion Department of Agriculture, Ottawa. Distinguished for his elucidation of the mechanism of sexual reproduction of the Rust Fungi and for his studies of the genetics and epidemiology of the cereal Rusts. He has made notable contributions to scientific agriculture in Canada.

Dyson, Freeman John. Associate Professor of Theoretical Physics at the Floyd Neuman Laboratory of Nuclear Studies, Cornell University, Ithaca, N.Y., U.S.A. Distinguished for his discoveries in the geometry of numbers and for his contributions to quantum electrodynamics.

Fell, Honor Bridget. Foulerton Research Fellow of the Royal Society, Director of the Strangeways Research Laboratory, Cambridge. Distinguished for her researches on the development and differentiation of tissues and rudiments of organs *in vitro*. She has made fundamental contributions to knowledge of the mechanisms governing cartilage and bone formation.

Hammick, Dalziel Llewellyn. Aldrichian Praelector in Chemistry, Oxford University. Distinguished for his work in physical chemistry, especially in the application of physical methods in the study of organic chemical reactions.

Hawkes, Leonard. Professor of Geology, Bedford College, London University. Distinguished for his researches in igneous geology and petrology, especially of Iceland.

James, William Owen. Reader in Botany (Plant Physiology), Oxford University. Distinguished for his studies in plant physiology, in particular for his contributions to our present understanding of the catalytic mechanisms of respiration in higher plants, and of the relation of respiration to plant syntheses.

Jones, Harry. Professor of Mathematics, Imperial College of Science and Technology, London University. Distinguished for his contributions to the theory of the solid state and the detonation processes of solid explosives.

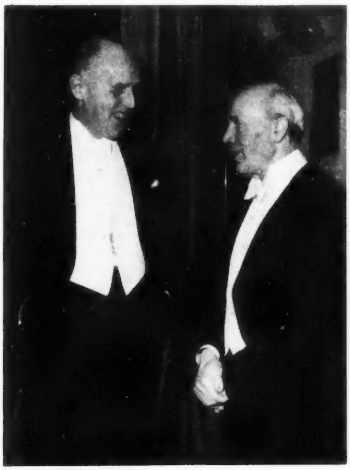
Katz, Bernhard. Professor of Biophysics, University College, London. Distinguished for his contributions to neurophysiology, particularly in respect of nervous impulses and muscle end-plate potentials.

Lemberg, Rudolf. Director, Biochemical Department of the Institute of Medical Research, Royal North Shore Hospital, Sydney. Distinguished for his contribution to the study of the metabolism of pigments derived from haemoglobin. He has initiated new botanical researches through his discovery of pigments of the bile type in plants.

McCrea, William Hunter. Professor of Mathematics in the University of London. Distinguished for his contributions to theoretical astrophysics and cosmology.

Mitchell, Joseph Stanley. Professor of Radiotherapeutics, Cambridge University, and Director of the Radiotherapeutic Centre, Addenbrookes Hospital. Distinguished for his work in biophysics and radiotherapy. He has materially contributed to our knowledge of the effects of radiation on metabolic processes.

Offord, Albert Cyril. Professor of Mathematics, Birkbeck College, London. Distinguished for his contributions to Fourier analysis and the theory of integral functions.



Sir Wallace Akers (left), *who heads this year's list of new F.R.S.s, is an outstanding scientific administrator. A chemistry graduate of Oxford, he went from Christ Church College to Brunner Mond in 1911 and subsequently became a director of I.C.I. Ltd. During the war he directed atomic energy research for the Ministry of Supply.*

Pugsley, Alfred Grenville, O.B.E. Professor of Civil Engineering, Bristol University. Distinguished for his contribution to the reliability of aircraft structures, the design of which has been much influenced by his researches.

Race, Robert Russell. Serologist, Medical Research Council, Lister Institute. Distinguished for the application of serological methods in human genetics, and of genetics in medicine. In particular he is principally responsible for the progressive elucidation of the complicated genetical situation found in connexion with the Rhesus and other factors capable of causing haemolytic disease.

Ryle, Martin. Lecturer in Physics, Cambridge University. Distinguished for his leadership of the Cambridge School of Radio-astronomy.

Smith, David MacLeish. Chief Engineer, Gas Turbine Department, Metropolitan-Vickers Electrical Co. Ltd. Distinguished for his contributions to the theory and design of steam and gas turbines and axial flow air-compressors, and their applications to aircraft, marine propulsion, the railway locomotive, and industrial use.

Spring, Frank Stuart. Professor of Organic Chemistry in the Royal Technical College, Glasgow. Distinguished for research in organic chemistry, particularly in the field of sterols, of triterpene resinols and related acids and of heterocyclic compounds with antibiotic activity.

Taylor, Edward Wilfred, C.B.E. Joint Managing Director of Cooke, Troughton and Simms, Ltd. Distinguished for his contributions to the development of optical instruments used in surveying and phase-contrast microscopy.

Tolansky, Samuel. Professor of Physics, Royal Holloway College, University of London. Distinguished for his contributions to the fine structure of spectral lines, the determination of nuclear spin, and new types of interference fringes.

Vogt, Marthe. Lecturer in Pharmacology, University of Edinburgh. Distinguished for her work on the quantitative estimation of the cortical hormone in adrenal venous blood, and for her discovery of the various factors which control the output of this hormone.

Westoll, Thomas Stanley. Professor of Geology in the University of Durham. Distinguished for his palaeontological investigations of Palaeozoic fishes and especially on their relationships with the amphibia.

Woods, Donald Devereux. Reader in Microbiology, Oxford University. Distinguished for his contributions to bacterial chemistry and particularly for the explanation of the antibacterial action of sulphonamides. The reversal of this action by para-amino-benzoic acid is a contribution of fundamental importance.

THIS MONTH'S COVER PICTURE shows a male sea-horse surrounded by young; one baby sea-horse is seen here in process of being expelled from the male's brood-pouch.

There are several species of sea-horse; one of them (*Hippocampus guttulatus*) is met with occasionally in British waters. The peculiar feature of this genus of fishes is the incubation of the eggs in the brood-pouch of the male. Incubation takes about a week to complete, but a period as long as a month can elapse before all the young are expelled from the brood-pouch. After that there is no further sign of parental care; the parents' assignment ends with the release of the young from the male's pouch.

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Night Sky in May

The Moon.—Full moon occurs on May 9d 20h 16m, U.T., and new moon on May 23d 19h 28m. The following conjunctions with the moon take place:

May			
7d 02h	Saturn in conjunction with the moon,	Saturn	7° N.
9d 03h	Mars ,,	Mars	6° N.
21d 21h	Jupiter ,,	Jupiter	6° S.
22d 10h	Mercury ,,	Mercury	7° S.

In addition to these conjunctions with the moon, Venus is in conjunction with Jupiter on May 5d 14h, Venus 0·3° S., and Mercury is in conjunction with Jupiter on May 17d 02h, Mercury 1·8° S.

The Planets.—Mercury, a morning star, is too close to the sun during the month for observation, and the same applies to Venus. Mars, in opposition to the sun on May 1, can be seen throughout the night, and does not set till the early morning hours. Jupiter, a morning star, is too close to the sun to be observed in the earlier part of May but can be seen later in the month, rising at 2h 30m on May 31. Saturn, in the constellation Virgo, sets at 3h 55m, 3h, and 2h on May 1, 15, and 31, respectively, and about the middle of the month is very close to γ Virginis. Attention has already been drawn to the conjunction of Saturn with the moon on May 7, on which day the moon sets at 3h.

A conspicuous constellation during May is Cygnus, also called the Northern Cross, and it resembles both a flying swan—from which it got its name Cygnus—and also a cross. You will have no difficulty in identifying Deneb or α Cygni at one end of the cross, at the other end of which is β Cygni which a small telescope or even field-glasses will show to be a very beautiful double star. One component is yellow and the other a beautiful blue, and the contrast presents a remarkable sight. A more interesting star is 61 Cygni which is just visible to the naked eye provided one knew where to look for it. This was the first star whose distance was determined, and within recent years something resembling a very massive planet has been believed to be revolving round one of the components of the system (61 Cygni is a double star). If this should prove correct it would suggest the possibility that many stars have planetary systems—and, indeed, this is believed by some astronomers but it is incapable of proof at present. If a star comparatively close to us—about 10 light-years distant—has at least one planet, it might be assumed that many other stars which are too far away for planets belonging to them to be detected have also planets revolving around them.

The British Contribution to Television

A CONFERENCE rivalling in interest the famous Radar Convention of 1946 was held at the Institution of Electrical Engineers from April 28 to May 3. Organised by the Radio Section of the Institution, it covered all aspects of television engineering in Britain in ten sessions of papers—more than sixty contributions from the leading television engineers of the country.

After the opening ceremony an interesting paper on the history of television was given by G. R. M. Garratt and A. H. Mumford, who said: "Modern television owes much to the researches and achievements of many distinguished workers, but in essence it has been developed upon the fundamental lines first suggested by Campbell Swinton."

Following sessions dealt with: Programme Origination; Broadcasting Stations; Propagation; Point-to-point Transmission; Industrial Television; Receiving Equipment; Circuits; General System Aspects.

The paper on Industrial Television was of unusual interest, as it showed ways in which a science developed mainly for entertainment could be applied to processes and research which would not be possible to undertake by ordinary means. The recent finding of the *Affray* by an underwater television camera was cited as one application in which the human element could be replaced by a more robust organism which, however, had its limitations at present in having no hands.

Among the special applications of television technique mentioned were the use of the flying-spot microscope (which observers have said to be capable of giving higher resolution than the projection microscope), the use of the television camera in stroboscopic observations, and the ultra-sensitive camera for operating at levels of illumination to which a fast photographic plate is insensitive.

In the final paper Mr. L. C. Jesty surveyed television as a problem in telecommunications. In order to conserve space in the ether it is becoming increasingly important to achieve maximum efficiency in transmitting television signals, and it is possible that novel, though expensive, methods of compressing television signals may have to be adopted. The peculiar problems of colour television are appreciated, and even in monochrome pictures the full theoretical performance is seldom achieved in modern receiver practice.

As a relief from the formal papers and discussions the members paid visits to various broadcasting centres and industrial organisations, and the week's proceedings ended on a light note with a ball at Grosvenor House, when various B.B.C. notabilities (who were better known to the guests than the engineers behind the programmes!) were present.

Great credit is due to the Secretary of the Radio Section, Mr. G. A. Ingram, B.Sc., on whom most of the organisation fell, and to the Chairman, Dr. D. C. Espley, and members of the Radio Section Committee who arranged the Convention and selected the subject-matter of the papers.

Those readers who were not able to attend and who would like to have copies of the papers can obtain them from the Secretary, The Institution of Electrical Engineers, Savoy Place, W.C.2, price £3 3*s*. the set.

The Convention was well timed in that a number of European countries are still making up their minds about the standard to be adopted for their service. By demonstrating the success of a nation-wide television system such as is now operating, it is hoped that some other countries may be persuaded that the efficiency of the television service is not only measured by the number of lines it is possible to cram into the picture.

Russia Leads as Usual

A CHARACTERISTIC article in the Russian publication *Soviet Union* claims that Russia is superior in television development as in all other things. After the statement that the theoretical principles of television were formulated as far back as 1880 by a Russian physicist, it adduces Rosing's patent of 1907, Katayev's patent of 1931, and Braude's patent of 1938 as "indisputable proof of the Soviet Union's priority in the invention and further improvement of high quality television".

Regarding the British standard of 405 lines, the article says: "Anybody who knows anything about television will understand that a 625-line scanning standard will produce a more perfect definition than 405 lines. . . . But this calls for a high standard of engineering. It is doubtful whether the British attempt to present technical backwardness as a virtue will convince anybody." Now we know!

The Spread of Scientific Information

FROM a handout about the third edition of the *World List of Scientific Periodicals* to be published as a book this July by Butterworths Scientific Publications, it is astonishing to learn that during the last twenty years the number of scientific periodicals published has been increasing at the rate of almost one thousand *every year*.

The second edition of the "World List" published in 1934 listed 36,000 journals. The third edition will list about 54,000, an increase of 50%, which covers new periodicals published between 1930 and 1950.

The *World List of Scientific Periodicals* started as a compilation of the British Museum in 1920, with the aid of a grant from the Carnegie United Kingdom Trust. With the publication of its second edition in 1934 it rapidly became a major work of reference. It consists of a list of the scientific, technical and medical journals and periodicals of the world numbered serially and arranged in alphabetical order. The full title of each journal is followed by the internationally recognised standard abbreviation of its title, together with a list of the libraries in Great Britain which file the journal. Where a journal has changed its title, the new title is cross-referenced with the old, so that the complete file can be traced.

The following is the entry concerning DISCOVERY: 7423 Discovery. London. *Discovery*. [1920–] L.AM. 48–; BM.; BMN.; G.; H. 45–; IC. 43–; IN. 43–; L. 43–; P.; PL. 45–; PR. 44–; SC.; U. imp.; UC. 22–36 imp.; ABS.A. 45–; N.; U. 20–21; BM.C. 45–; P.; U.; BN.U.; BR.P. 21–; U. 32–; C.UL.; CN.R. 43–; CR.M.; DB.; DN.U. 20–27; E.N.; B. 22–; N. 43–; R. 20–29; T. 47–; EX.U. 21–33: 47–; G.M.; U.; H.U. 38–; LD.P.; U. 20–28: 47–; LH.P. 44–; LV.P. 20–38: 43–; M.L.;

MS. 20–39 imp.; P.; R.; U.; N.P. 20–37; U. 28–; NW.P.; O.R.; RT. 20–43; SH.P. [*Suspended between March, 1940, and January, 1943.*] This shows that DISCOVERY was first published in 1920 and publication was suspended between March 1940 and January 1943. Complete files of DISCOVERY are available at the following libraries:

London: British Museum, British Museum of Natural History, Royal Geographical Society, Patent Office, Science Museum. *Wales*: National Library, National Museum. *Birmingham*: Public Library, University Library. *Cambridge*: University Library. Dublin Libraries (Joint University Libraries). *Edinburgh*: Royal (Dick) Veterinary College. *Glasgow*: Mitchell Library, University Library. *Leeds*: Public Library. *Manchester*: Rylands Library, Public Library, University Library. *Newcastle*: Public Library. *Oxford*: Radcliffe Science Library. *Sheffield*: Public Library.

Material which appeared in early issues of DISCOVERY can be copied for readers photographically by the British Museum, the Patent Office Library, and the Science Museum, South Kensington, on payment of the cost of copying.

* * * * *

LATEST publication of the National Coal Board is a revised edition of *Books about Coal*. This can be obtained on application to the National Coal Board (Public Relations Branch), Hobart House, Grosvenor Place, London, S.W.1.

Appert's Centenary

IN our February 1952 issue we published a note about APPERT, the inventor of canning. We have since received from a reader a copy of *La Revue de la Conserve de France et de l'Union Française* (1 Rue de la Réale, Paris 1), and from this it seems that there is a great deal of doubt about the date of his birth and his place of birth. An article written by M. P.-H. Lenoir, director of Maison Amieux Frères, and published under the title of "Nicolas Appert, Benefactor of Mankind", suggests he was born in 1750 at Châlons-sur-Marne, or Châlons-sur-Vesle.

On June 3, 1951, at a town called Massy-Palaiseau, there was a commemorative meeting at which M. R.-V. Manaut delivered an address in which he gave Appert's birthday as October 23, *1752*, and his birthplace as Châlons-sur-Marne.

Volume III of the *Dictionary of French Biography* (French equivalent of the Dictionary of National Biography) is considered to contain the most careful study yet made of the details of Appert's life, and this reaches no definite conclusions about his date of birth. The entry gives the date as "about 1750", and adds that Appert was born "en l'un des Châlons de Champagne". His full name was either Nicolas François Appert *or* Nicolas Charles Appert. Apparently the only official State record about Appert is the following registration of his death which reads as follows:

«Le 1er juin 1841 est décédé à Massy... le sieur Nicolas Appert, né à Châlons (Marne), fils des époux Claude Appert et Marie Huet. Il était veuf d'Elisabeth Benoist. Décédé à l'âge de 91 ans.»

It seems impossible to come to any definite conclusion about his birth. The records of Châlons-sur-Vesle, kept in the bishop's palace at Reims, were destroyed in the last war. At Châlons-sur-Marne one only finds the birth certificates of a *Pierre Appert* (born November 8, 1750) and a *Nicolas Appert* (born October 23, 1752), but both boys were the sons of *Jean Appert*, wool-comber, and of *Marie Bonvalet*, and not of Claude Appert and Marie Huet.

The Original Orrery

THE first orrery ever constructed has been lent by the present Earl of Cork and Orrery to the Science Museum, and is on temporary display among the Astronomy Collections. It will be transferred to the Special Exhibition, "The British Clockmaker's Heritage", which opens this month.

Orreries were designed to show the motions of the sun, moon and earth, and to ensure accurate representations of these motions they contain complicated and delicate wheel-work. It is therefore not surprising that their construction was undertaken by clockmakers such as Graham and Tompion. This example was made by John Rowley in about 1716 for Charles Boyle, fourth Earl of Orrery.

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